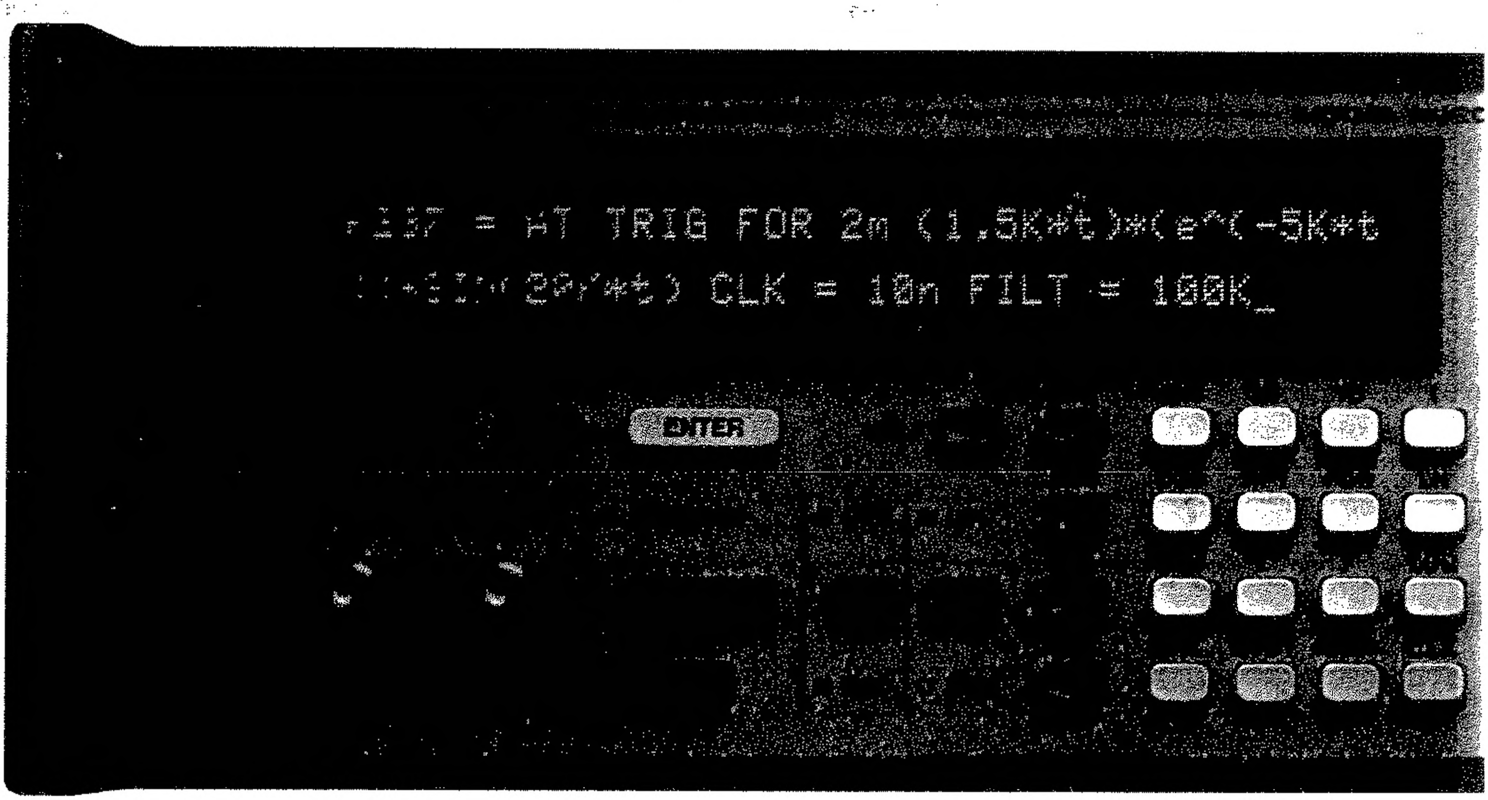
ANALOGIC®

DATA PRECISION®

Polynomial Waveform Synthesizers



USERS MANUAL
MODEL 2020
MODEL 2000

SOFTWARE EFFECTIVITY REV 3.01

82-5016 REV A

...new directions in signal generation

TABLE OF CONTENTS

GETTING STARTED:

This manual covers the DATA PRECISION model "2020" Signal Generator including a sub-set model "2000". The model "2000" differs from the "2020" in that it is for remote operation only (no key panel or display), and it does not communicate with the DATA PRECISION model "6000" Waveform Analyzer. For additional details on the model "2000", refer to the "2000" Section (sec. F) of this manual.

Before connecting the instrument (2020 or 2000) to an ac power source be sure that the power source (115 Vac or 220 Vac) matches the voltage selection on the rear panel of the instrument and verify that the power source is of the third wire grounded type. Figure A-2 shows the line voltage selection detail and describes the fuse ratings to be used.

As you become familiar with the operation and capabilities of the 2020 it will become apparent that the versatility afforded by this instrument will eliminate the need for a multitude of classical signal sources.

Figure AF-1 shows the Model "2020" front panel. An examination of this drawing will provide your first step in understanding as well as an immediate feeling for the ease of use and clean human factors interface that the "2020" will provide to you, the operator.

There are four basic modes by which the 2020 formulates its output signal:

1. Standard Modes; by which classical waveshapes such as square, pulse, sine, triangle, sawtooth, etc. are readily generated.
2. Polynomial Mode; by which waveshapes are generated from user supplied mathematical expressions of the form Y = f(t). User expressions of this form can be named and stored in internal non-volatile memory.
3. Real World waveforms can be captured (digitized) on the Data Precision Model "6000" Waveform Analyzer and downloaded to the "2020" for replication without the need for an additional controller.
4. Predetermined digital pattern data can be down-loaded from any intelligent host (via IEEE-488 or RS232) for analog generation by the "2020".

Note: Item 3, above, requires the normal or high speed GPIB 488 option and Item 4 requires the same option or the RS232 option. Other options include a math co-processor to speed the execution of Item 2 above, as well as output memory size options and additional non-volatile memory. To determine the installed options, key in the sequence [2nd] [OP] [7] [ENTER] and scroll through the displayed text with the DOWN CURSOR key. Press [RESTORE] to exit the review of installed options.

HELP

A QUICK UNDERSTANDING OF THE USE AND FUNCTION OF ANY OR ALL OF THE FRONT PANEL KEYS CAN BE OBTAINED BY USING THE BUILT IN "HELP" FEATURE. Pressing the HELP key places the instrument into the HELP TEXT MODE. While in this mode, pressing any front panel key will bring to the display a brief explanation of that key. To EXIT the HELP mode press the HELP key again. There is also a HELP feature associated with the OP CODE routines. Pressing [2nd] [OP] [HELP] will bring the OP CODE directory to the display which can then be scrolled by use of the DOWN ARROW key. The OP CODE Section of this manual contains a more detailed explanation of these routines which are used for specialized applications, configuration set-ups, etc.

Figure AF-3 shows the location of the signal output fuse as well as the location of its spare. This is the fuse that you will be looking for if on power-up the display shows an "output fuse blown" message. Before replacing this fuse, determine the nature of the output abuse that caused the disruption so that it does not recur. The output will tolerate either a short circuit or low (less than 10V) reverse voltage without blowing the fuse. However, in the case of severe abuse (up to 115 Vac),

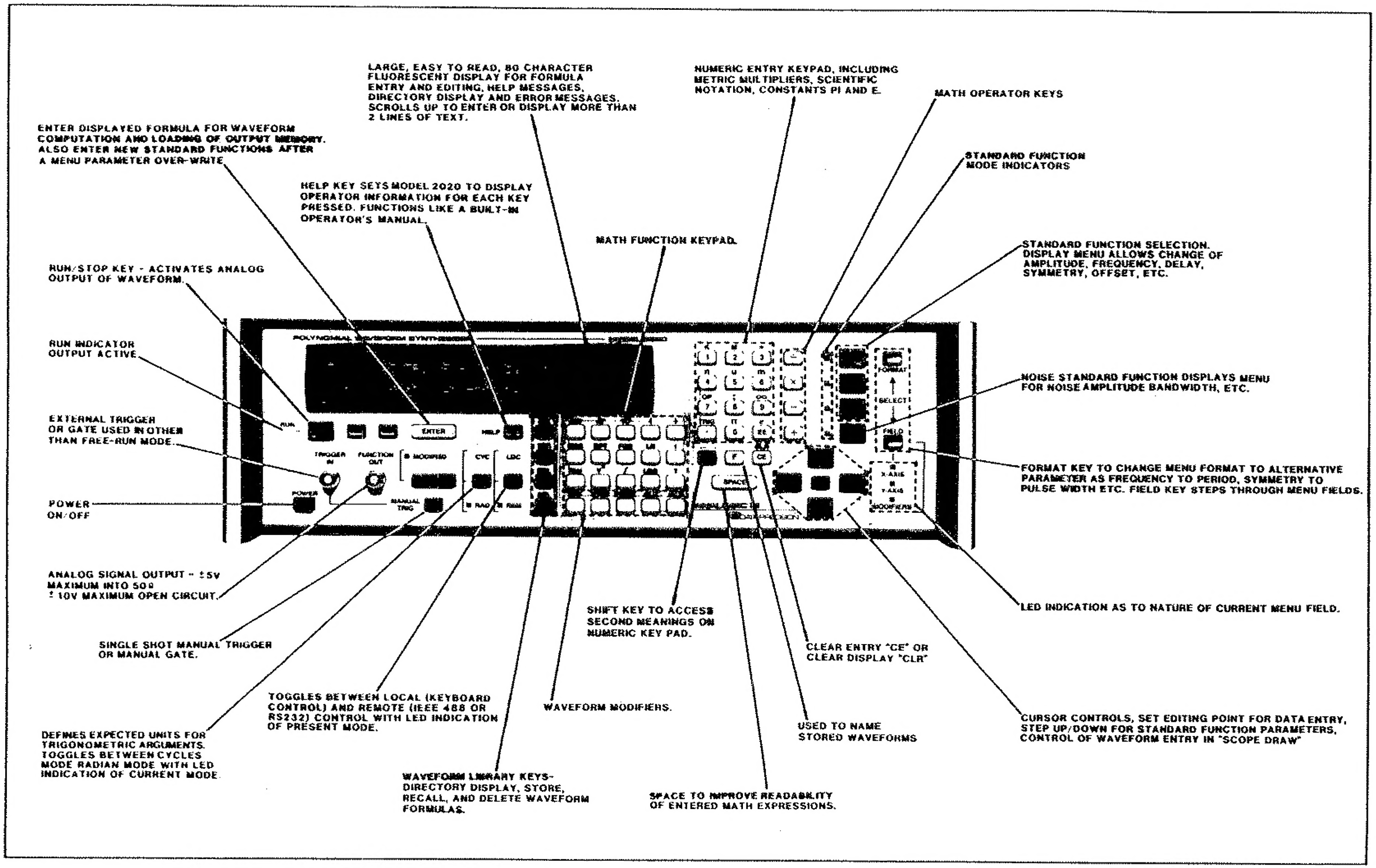

LARGE, EASY TO READ, 80 CHARACTER FLUORESCENT DISPLAY FOR FORMULA ENTRY AND EDITING, HELP MESSAGES, DIRECTORY DISPLAY AND ERROR MESSAGES. SCROLLS UP TO ENTER OR DISPLAY MORE THAN 2 LINES OF TEXT.
NUMERIC ENTRY KEYPAD, INCLUDING METRIC MULTIPLIERS, SCIENTIFIC NOTATION, CONSTANTS PI AND E.
MATH OPERATOR KEYS
ENTER DISPLAYED FORMULA FOR WAVEFORM COMPUTATION AND LOADING OF OUTPUT MEMORY. ALSO ENTER NEW STANDARD FUNCTIONS AFTER A MENU PARAMETER OVER-WRITE.
STANDARD FUNCTION MODE INDICATORS
HELP KEY SETS MODEL 2020 TO DISPLAY OPERATOR INFORMATION FOR EACH KEY PRESSED. FUNCTIONS LIKE A BUILT-IN OPERATOR'S MANUAL.
MATH FUNCTION KEYPAD.
STANDARD FUNCTION SELECTION. DISPLAY MENU ALLOWS CHANGE OF AMPLITUDE, FREQUENCY, DELAY, SYMMETRY, OFFSET, ETC.
RUN/STOP KEY - ACTIVATES ANALOG OUTPUT OF WAVEFORM.
RUN INDICATOR OUTPUT ACTIVE.
NOISE STANDARD FUNCTION DISPLAYS MENU FOR NOISE AMPLITUDE BANDWIDTH, ETC.
EXTERNAL TRIGGER OR GATE USED IN OTHER THAN FREE-RUN MODE.
FORMAT KEY TO CHANGE MENU FORMAT TO ALTERNATIVE PARAMETER AS FREQUENCY TO PERIOD, SYMMETRY TO PULSE WIDTH ETC. FIELD KEY STEPS THROUGH MENU FIELDS.
POWER ON/OFF
ANALOG SIGNAL OUTPUT - ±5V MAXIMUM INTO 50Ω ±10V MAXIMUM OPEN CIRCUIT.
SHIFT KEY TO ACCESS SECOND MEANINGS ON NUMERIC KEY PAD.
LED INDICATION AS TO NATURE OF CURRENT MENU FIELD.
SINGLE SHOT MANUAL TRIGGER OR MANUAL GATE.
CLEAR ENTRY "CE" OR CLEAR DISPLAY "CLR"
TOGGLES BETWEEN LOCAL (KEYBOARD CONTROL) AND REMOTE (IEEE 488 OR RS232) CONTROL WITH LED INDICATION OF PRESENT MODE.
WAVEFORM MODIFIERS.
DEFINES EXPECTED UNITS FOR TRIGONOMETRIC ARGUMENTS. TOGGLES BETWEEN CYCLES MODE RADIAN MODE WITH LED INDICATION OF CURRENT MODE.
USED TO NAME STORED WAVEFORMS
CURSOR CONTROLS, SET EDITING POINT FOR DATA ENTRY, STEP UP/DOWN FOR STANDARD FUNCTION PARAMETERS, CONTROL OF WAVEFORM ENTRY IN "SCOPE DRAW"
WAVEFORM LIBRARY KEYS- DIRECTORY DISPLAY, STORE, RECALL, AND DELETE WAVEFORM FORMULAS.
SPACE TO IMPROVE READABILITY OF ENTERED MATH EXPRESSIONS.

FIGURE AF-1

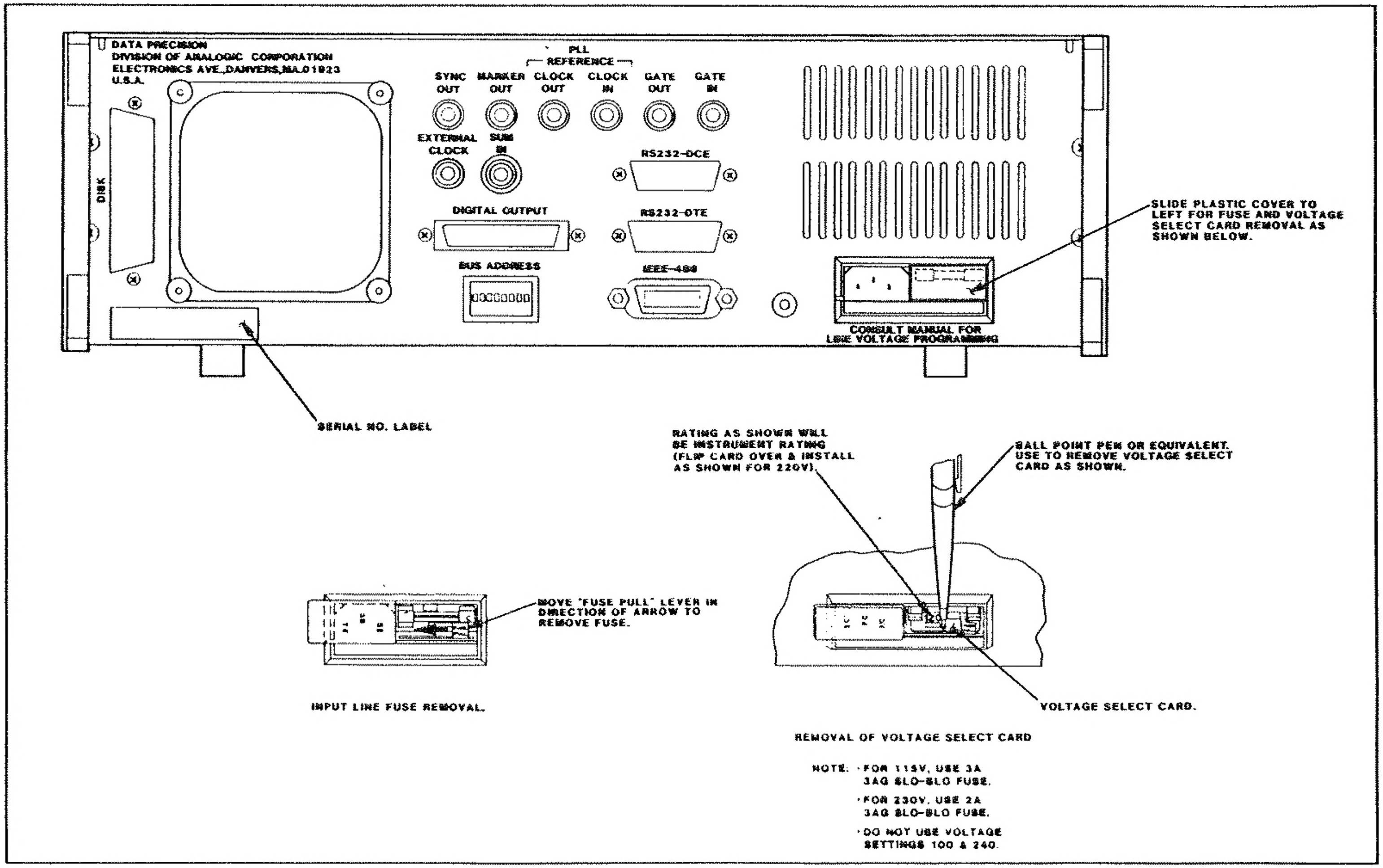

DATA PRECISION
DIVISION OF ANALOGIC CORPORATION
ELECTRONICS AVE.,DANVERS,MA.01923
U.S.A.
DISK
PLL
REFERENCE
SYNC OUT
MARKER OUT
CLOCK OUT
CLOCK IN
GATE OUT
GATE IN
EXTERNAL CLOCK
SUM IN
RS232-DCE
DIGITAL OUTPUT
RS232-DTE
BUS ADDRESS
IEEE-488
CONSULT MANUAL FOR LINE VOLTAGE PROGRAMMING
SLIDE PLASTIC COVER TO LEFT FOR FUSE AND VOLTAGE SELECT CARD REMOVAL AS SHOWN BELOW.
SERIAL NO. LABEL
RATING AS SHOWN WILL BE INSTRUMENT RATING (FLIP CARD OVER & INSTALL AS SHOWN FOR 220V).
BALL POINT PEN OR EQUIVALENT. USE TO REMOVE VOLTAGE SELECT CARD AS SHOWN.
MOVE "FUSE PULL" LEVER IN DIRECTION OF ARROW TO REMOVE FUSE.
INPUT LINE FUSE REMOVAL.
VOLTAGE SELECT CARD.
REMOVAL OF VOLTAGE SELECT CARD
NOTE: · FOR 115V, USE 3A 3AG SLO-SLO FUSE.
· FOR 230V, USE 2A 3AG SLO-SLO FUSE.
· DO NOT USE VOLTAGE SETTINGS 100 & 240.

FIGURE AF-2

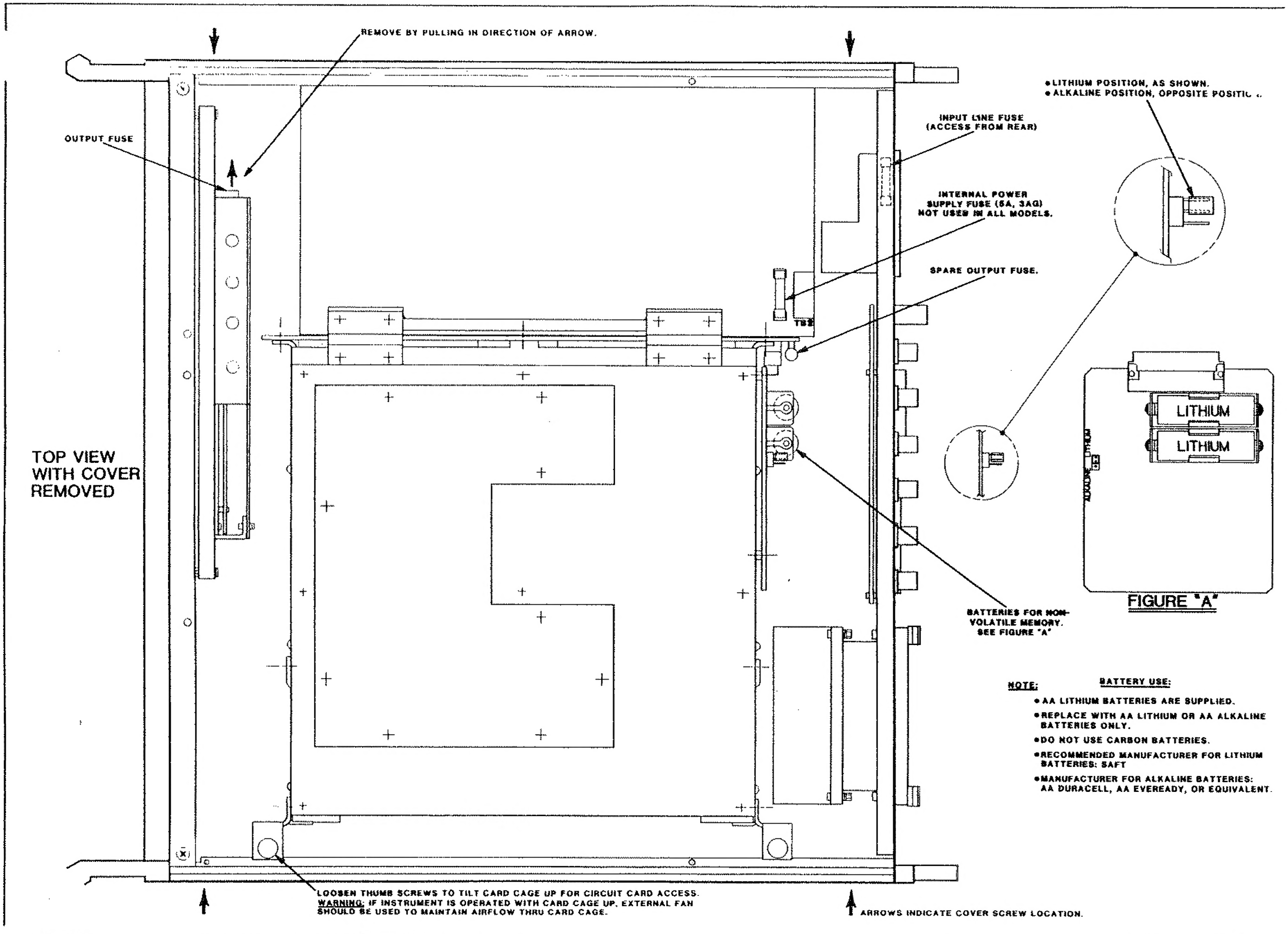

REMOVE BY PULLING IN DIRECTION OF ARROW.
OUTPUT FUSE
TOP VIEW WITH COVER REMOVED
• LITHIUM POSITION, AS SHOWN.
• ALKALINE POSITION, OPPOSITE POSITIC.
INPUT LINE FUSE (ACCESS FROM REAR)
INTERNAL POWER SUPPLY FUSE (5A, 3AG) NOT USED IN ALL MODELS.
SPARE OUTPUT FUSE.
TB2
LITHIUM
LITHIUM
FIGURE "A"
BATTERIES FOR NON-VOLATILE MEMORY. SEE FIGURE "A"
NOTE:
BATTERY USE:
• AA LITHIUM BATTERIES ARE SUPPLIED.
• REPLACE WITH AA LITHIUM OR AA ALKALINE BATTERIES ONLY.
• DO NOT USE CARBON BATTERIES.
• RECOMMENDED MANUFACTURER FOR LITHIUM BATTERIES: SAFT
• MANUFACTURER FOR ALKALINE BATTERIES: AA DURACELL, AA EVEREADY, OR EQUIVALENT.
LOOSEN THUMB SCREWS TO TILT CARD CAGE UP FOR CIRCUIT CARD ACCESS.
WARNING: IF INSTRUMENT IS OPERATED WITH CARD CAGE UP, EXTERNAL FAN SHOULD BE USED TO MAINTAIN AIRFLOW THRU CARD CAGE.
ARROWS INDICATE COVER SCREW LOCATION.

FIGURE AF-3

this fuse will prevent output stage damage. This figure also details the location and replacement detail for the non-volatile batteries. These batteries should last many years. If they do need replacing, a power-up "Low Battery" message will be displayed. Memory data should not be lost while changing the batteries provided that they are not left out of their holders for more than ten minutes or so.

CAUTION: If your load device (connected to the FUNCTION OUT connector) could be upset or damaged by a voltage that is within the output range of the "2020" ($\pm$10V into 50Ω or $\pm$20V open circuit) your load should be connected after "2020" is turned "ON". As is the general case with microprocessor-controlled signal generators, the output state cannot be established until the processor has initialized. Therefore, instantaneous voltages during the power-on transient could exist anywhere within the output stage voltage capability. Additionally, RUN [R/S] should not be executed until you have "ENTERED" the waveform that is to be RUN, i.e., Standard Function, Polynomial Function, DownLoaded Function, etc. After the "2020" is powered ON and before your first output waveform is executed, the FUNCTION OUT level will be about +300 mV.

There are no internal adjustments that can be made by the user. The amplitude accuracy is a matter of inherent design and is derived from a fixed reference cell. The time base accuracy is derived from a crystal referenced phase-lock-loop that is not adjustable.

This instrument has been designed for ease of operation and long life. If, however, you require either applications assistance or service information, please consult a Data Precision local representative or the factory in Danvers, Massachusetts.

HARDWARE/FIRMWARE VERSION AND INSTALLED OPTIONS

The Power-On message describes the hardware version (25 or 100 MHz) and Firmware revision number. Installed options can be determined by using the key sequence "[2nd] [OP] [7] [ENTER]". The down cursor arrow is used to view additional message lines when the "MORE" prompt is shown. Use [RESTORE] to exit the options listing mode.

CONNECTIONS: (OTHER THAN AC POWER)

Refer to front panel view shown in figure AF - 1

FUNCTION OUT

This is the Analog Signal output connector. The output is single ended (ground referenced) with a 50.0Ω source impedance. It's peak-to-peak signal swing capability is −5 to +5V into 50Ω or −10 to +10V into an infinite load impedance.

TRIGGER IN

This is the connector that is used to either trigger or gate the 2020 when it is operating in other than the Free-Run mode. The active threshold can be set to either zero-crossing or +1.0V by means of the OP 2020 configuration set-up (refer to OP CODE Section). Refer to the Triggering Modes descriptions in either the STANDARD FUNCTION and POLY Sections of this manual.

REAR PANEL (refer to rear panel view shown in figure AF-2) [PLL REFERENCE] **CLOCK IN**

This is a 25 kHz TTL logic signal that serves as the time base (PLL) reference when the instrument is configured as a Slave. Refer to the OP CODE section under OP 2020 and examine the MODE = description.

[PLL REFERENCE] **CLOCK OUT**

This provides the 25 kHz TTL output reference when the instrument is configured as a MASTER. As above, refer to the OP CODE Section of this manual under OP 2020.

GATE IN
This is a TTL logic input signal that is supplied by the GATE OUT of a MASTER 2020 instrument when this instrument is a SLAVE.

GATE OUT
This is a TTL logic output signal that occurs while this instrument is configured as a MASTER to drive the GATE IN of a SLAVE configured instrument. NOTE that GATE OUT and GATE IN are only relative to MASTER/SLAVE operations between two or more instruments.

SYNC OUT
This is a TTL active high logic signal that occurs at the beginning of each output waveform pass. It is particularly useful for synchronizing an oscilloscope for output waveform viewing.

MARKER OUT
This is a TTL active high logic signal that can be positioned to occur at any point during the output waveform duration. It is set by either an attribute statement in the POLY mode (refer to the POLY Section of this manual) or it is directly set as a menu field parameter in the STANDARD MODE (refer to the STD MODE section). In either case, it can be changed in time with the "MODIFIED" function that is described in the STD Function section.

EXTERNAL CLOCK
This is a logic level signal input that provides an output data clock to the "2020"/"2000" when the clock source configuration is set to EXTERNAL in the OP 2020 set-up routine; the logic threshold is configurable as either zero crossing or +1.0V. These selections are made in the OP 2020 configuration set-up routine (ref OP CODE Section).

SUM IN
This is an analog input signal that can be summed to the normal "2020"/"2000" analog output. The input impedance at this terminal is 50Ω with an effective bandwidth of dc to 35 MHz. The maximum usable input is ±0.25V and the maximum safe input is ±10V. The ratio of summed signal to internal (2020) signal is 1% (±10%) per 0.1V at the sum input. The allowable input range (±0.25V) yields a maximum sum input to internal signal ratio of 5%.

IEEE-488
This is a standard GPIB 488 connector that is used for remote (BUS) control of the 2020 when the GPIB option is installed. On the "2000" unit, GPIB is standard. Refer to Figure A-4 for a detailed pin-out of this connector.

RS232 (DCE) and RS232 (DTE)
These are RS232 remote control connectors that are used for Data Console and Data Terminal operation when the RS232 option is installed. Refer to Figures A-5 and A-6 for detailed pin-out assignment on these connectors. When connecting an IBM PC (or compatible) asynchronous communications interface (serial card) to the "2020", the 25 pin DCE port is connected directly to the 25 pin DTE port on the IBM PC interface card. However, in order to connect the DTE port on the "2020" to the DTE port on the IBM you must fabricate a "NULL MODEM" interconnect cable as follows:

"2020" Instrument End	**P.C. Serial Card End**
Pin 1 (Gnd)	Pin 1 (Gnd)
Pin 7 (Gnd)	Pin 7 (Gnd)
Pin 2 (TXD)	Pin 3 (RXD)
Pin 3 (RXD)	Pin 2 (TXD)
If the Serial Card utilizes DTR-DSR handshake:	
Pin 5 (CTS)	Pin 20 (DTR)
Pin 20 (DTR)	Pin 6 (DSR)
If the Serial Card utilizes RTS-CTS handshake:	
Pin 5 (CTS)	Pin 4 (RTS)
Pin 20 (DTR)	Pin 5 (CTS)

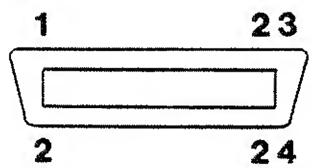
BUS ADDRESS AND COMMAND (CMD) DEVICE SETTING
This switch array is used to set the GPIB (default) Bus Address, 0 thru 31 when the GPIB option is installed and to specify the Command Device as either GPIB or RS232 (DTE or DCE). Figure A-7 describes the setting of these switches to obtain a particular address and CMD Device. This switch setting provides the DEFAULT Bus Address and CMD Device, both of which can be changed by either menu selection or Remote Bus Command.

LISTEN SERVICE REQUEST (SRQ) DEFAULT SETTING:
The rear panel switch assembly, shown in Figure AF-7, also has one switch that allows the instrument to default to either Listen SRQ=ON or OFF. The SRQ state is also reconfigurable by menu or Remote Bus Command.

DIGITAL OUTPUT
This connector provides the Digital Data Output which is standard on the 25 MHz version (Figure AF-8) utilizing TTL format and optional on the 100 MHz version (Figure AF-9) which utilizes differential ECL.

REAR PANEL ADJUSTMENTS:
There are two (2) recessed screwdriver adjustments on the rear panel. They are labeled "CLOCK DELAY" and "GATE DELAY". These adjustments are relevant only when one "2020" is acting as a MASTER with one or more (2020) SLAVE units. Additionally, the adjustments are only effective on the unit which is acting as MASTER. In order to compensate for inter-unit cable delays, the "CLOCK DELAY" adjustment on the MASTER unit is used to bring the Data Clock phase on the multiple "2020" units into coincidence. Likewise, the "GATE DELAY" adjustment is made to bring the waveform start (trigger) times into coincidence on the multiple "2020" units.

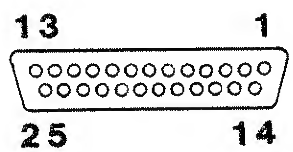
IEEE-488



PIN ASSIGNMENTS			
PIN	DESCRIPTION	PIN	DESCRIPTION
1	DIO1 *	15	NDAC *
2	DIO5 *	16	GND
3	DIO2 *	17	IFC *
4	DIO6 *	18	GND
5	DIO3 *	19	SRQ *
6	DIO7 *	20	GND
7	DIO4 *	21	ATN *
8	DIO8 *	22	GND
9	EOI *	23	SYSGND
10	REN *	24	GND
11	DAV *		
12	GND		
13	RNFD *		
14	GND		

FIGURE AF-4

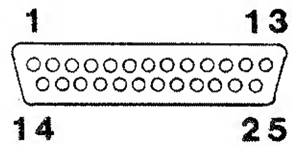
RS232 DCE



PIN ASSIGNMENTS			
PIN	DESCRIPTION	PIN	DESCRIPTION
1	GND	15	
2	RXDA	16	
3	TXDA	17	
4		18	
5	CTSA	19	
6		20	DTRA
7	GND	21	
8		22	
9	GND	23	
10	GND	24	
11		25	
12			
13			
14			

FIGURE AF-5

RS232 DTE



PIN ASSIGNMENTS			
PIN	DESCRIPTION	PIN	DESCRIPTION
1	GND	15	
2	JXDB	16	
3	RXDB	17	
4		18	
5	CTSB	19	
6	PULL UP	20	DTRB
7	GND	21	
8	PULL UP	22	
9	GND	23	
10	GND	24	
11		25	
12			
13			
14			

FIGURE AF-6

BUS ADDRESS AND COMMAND DEVICE and LISTEN SRQ SETTING:

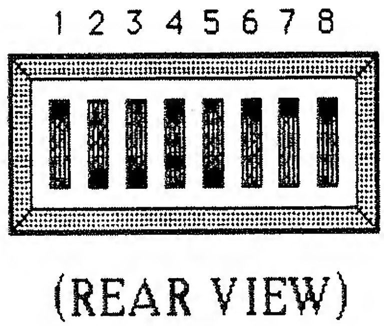


FIGURE AF-7

Figure AF-7 shows the rear panel slide switch assembly that sets the Default Command Device, Listen SRQ default and GPIB bus address. Switch position 1 determines the Listen SRQ default mode. Switch positions 2 & 3 are used to select the command device as either GPIB (IEEE-488) or RS232 (DTE or DCE connector). Switch positions 4, 5, 6, 7 & 8 are used to specify the GPIB bus address in a binary coded manner where position 8 is the LSB. Command Device selection, GPIB Bus Address and the Listen SRQ default can be changed by remote software control or by using the appropiate OP configuration menu (ref. OP Code and Remote Sections).

SETTING DEFAULT LISTEN SRQ MODE:

Switch position 1 UP	Listen Service Request (SRQ) enabled
Switch position 1 DOWN	Listen Service Request (SRQ) disabled

SETTING DEFAULT COMMAND (CMD) DEVICE:

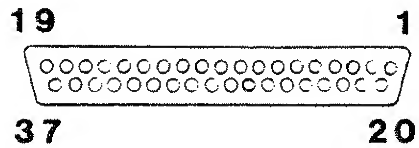
Switch num.	2	3	DEVICE	
	D	D	GPIB	Note: "U" switch UP
	D	U	RS-232 (DCE) Ser 0	"D" switch DOWN
	U	D	RS-232 (DTE) Ser 1	refer to rear view
	U	U	GPIB	shown above (AF-7)

SETTING THE DEFAULT GPIB BUS ADDRESS:

Switch Num. 4 5 6 7 8	ADDR	Switch Num. 4 5 6 7 8	ADDR	Switch Num. 4 5 6 7 8	ADDR
D D D D D	00	D U D U U	11	U D U U D	22
D D D D U	01	D U U D D	12	U D U U U	23
D D D U D	02	D U U D U	13	U U D D D	24
D D D U U	03	D U U U D	14	U U D D U	25
D D U D D	04	D U U U U	15	U U D U D	26
D D U D U	05	U D D D D	16	U U D U U	27
D D U U D	06	U D D D U	17	U U U D D	28
D D U U U	07	U D D U D	18	U U U D U	29
D U D D D	08	U D D U U	19	U U U U D	30
D U D D U	09	U D U D D	20	U U U U U	31
D U D U D	10	U D U D U	21		

25 MHz

DIGITAL OUTPUT



BACK PANEL VIEW

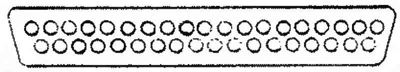
PIN ASSIGNMENTS			
PIN	DESCRIPTION	PIN	DESCRIPTION
1	GND	21	DATOUT 1
2	GND	22	DATOUT 2
3	GND	23	DATOUT 3
4	GND	24	DATOUT 4
5	GND	25	DATOUT 5
6	GND	26	DATOUT 6
7	GND	27	DATOUT 7
8	GND	28	DATOUT 8
9	GND	29	DATOUT 9
10	GND	30	DATOUT 10
11	GND	31	DATOUT 11
12	GND	32	DATOUT 12
13	GND	33	DATOUT 13
14	GND	34	DATOUT 14
15	GND	35	DATOUT 15
16	GND	36	–
17	GND	37	DATCLOCK
18	GND		
19	GND		
20	DATOUT Ø		

TTL SIGNALS

FIGURE AF-8

100 MHz

DIGITAL OUTPUT



BACK PANEL VIEW

PIN ASSIGNMENTS			
PIN	DESCRIPTION	PIN	DESCRIPTION
1	GND	21	DATOUT 14 *
2	DATOUT 15	22	DATOUT 13 *
3	DATOUT 14	23	DATOUT 12 *
4	DATOUT 13	24	DATOUT 11 *
5	DATOUT 12	25	DATOUT 10 *
6	DATOUT 11	26	DATOUT 9 *
7	DATOUT 10	27	DATOUT 8 *
8	DATOUT 9	28	DATOUT 7 *
9	DATOUT 8	29	DATOUT 6 *
10	DATOUT 7	30	DATOUT 5 *
11	DATOUT 6	31	DATOUT 4 *
12	DATOUT 5	32	DATOUT 3 *
13	DATOUT 4	33	DATOUT 2 *
14	DATOUT 3	34	DATOUT 1 *
15	DATOUT 2	35	DATOUT 0 *
16	DATOUT 1	36	DATCLK
17	DATOUT 0	37	GND
18	DATCLK *		
19	GND		
20	DATOUT 15 *		

ECL(DIFFERENTIAL)
* DENOTES ACTIVE LOW

FIGURE AF-9

STANDARD FUNCTION MODES:

There are four standard function modes:

1. SQUARE WAVE (includes PULSE MODE)
2. SINE WAVE
3. TRIANGLE WAVE (includes SAWTOOTH MODE)
4. NOISE

Any one of the four standard function modes is invoked by depressing the appropriate key showing a symbol corresponding to a square wave, sine wave, triangle wave, or labeled NOISE. When one of the four standard modes is selected, the LED indicator □ next to the mode key will illuminate and remain on as long as the selected mode is invoked.

Each standard function mode will bring menu fields to the display to enable the operator's selection of certain waveform parameters relevant to the invoked function. Each of these menu fields is preset with a default value or condition. For example, frequency is preset to 1.00000 kHz. One of the fields will contain a cursor to indicate the active field; that is, the field that is subject to change. The select cursor can be sequentially jumped to the next right most field by depressing the key marked "FIELD" or by simultaneously depressing the keys marked "FAST" and "RIGHT ARROW"; the cursor can be jumped to the next left most field by simultaneously depressing the keys marked "FAST" and "LEFT ARROW". The cursor can be moved under particular digits within the numerical value of the current (selected) field by depressing either the "LEFT ARROW" or the "RIGHT ARROW" keys without "FAST".

There are two methods available for changing the numerical value of a particular field parameter. They are "slew" and "direct overwrite". To slew a value, place the cursor under the digit to be slewed and repeatedly depress the "UP ARROW" to increment the digit or the "DOWN ARROW" to decrement the digit. Carry to more significant digits is automatic. If the run LED □ is lit, the slew will be considerably slowed down by an internal re-computation process between each successive value. To avoid this, depress the "R/S" (run-stop) key to disable the output until the displayed value is satisfactory, then activate the output (R/S) at which time only one re-compute process will be invoked. Or, with the "RUN" LED □ on (output active), depress the "FAST" key simultaneously with the up or down arrow key. In the latter case, the displayed value will change but the output function will not be updated until the "FAST" key is released. In the second method to overwrite a numerical value, simply enter the desired value using the numerical keypad. The overwrite can be started with the cursor under any digit in the current field value. In the direct overwrite method, the use of a decimal point is optional and the use of suffix notation such as M (Meg), k (kilo), m (milli), μ (micro) is optional. The suffix notation is located as a shift on the numerical keypad and is accessed by preceding the numeral key with the blue "2nd" key. For example, [K] is located over the numeral 1 key, therefore to enter 2.67 kHz, one would use the following key sequence: [2] [.] [6] [7] [2nd] [1]. When the desired value entry is complete, you MUST press "ENTER" to execute the value change and the "RUN" LED □ must be on (R/S key) if you expect to see the new value at the FUNCTION OUT connector.

After a numerical value change is made by either of the above methods and a re-compute is invoked by run ON (preceded by "ENTER" in the case of a direct overwrite), the displayed value may change to the nearest realizable value, if the requested value cannot be exactly synthesized. The new displayed value is the actual value being provided by the 2020. When a field value has been changed but not yet executed, the entire field value will be blinking as a reminder that "ENTER" is required to execute the changed value.

To change field parameters that are non-numeric such as trigger mode options or noise on/off; use the "UP" or "DOWN" arrow keys to cycle through the available alternatives.

Some fields can be expressed in alternate forms such as FREQUENCY/PERIOD or DUTY CYCLE/PULSE WIDTH. Fields that have an alternate units form are identified with a colon (:) instead of the equal sign (=) that is used for fixed format field parameters. The displayed field format is changed by pressing the "FORMAT" key while the select cursor is in the field to be changed. Each depression of the "FORMAT" key toggles between the alternate format forms. Since the selection is actually expressing the same parameter in alternate units, a change to the numeric value in one format automatically changes the value of the alternate form. For example, if the frequency is 1.00000 kHz, depressing "FORMAT" will cause the display to show PER:1.00000m (period is 1 ms). If the period is changed to 500μ (500 μs) a "FORMAT" key toggle will cause the display to show FREQ:2.00000K. Note that the parameter value can be specified or slewed in either format. The fields that have format alternatives are shown in the menu field illustrations which follow, as distinguished by the colon (:) notation.

Field values and/or conditions are carried between standard function modes, except for DLY (delay). That is, if the operator changes the frequency value in the square wave mode and then changes the mode to, for instance, sine wave, the frequency will remain at its last setting (the one specified in the previous mode).

The menu fields and default values for the SQUARE WAVE MODE are as follows:

```
FREQ:1.00000K    AMP:1.00000     OFST:0.00000
FILT=NONE        MARK:0.00000    TRIG=FREE RUN
NOISE= ON        NAMP=0.00000    NBW=200 KHz
DLY=0.00000      DUTY:50.0000%
```

NOTE: FORMAT **KEY CHANGES THE FOLLOWING FIELDS:**

```
FREQ changes to   PER: 1.00000m
DUTY changes to   PLSW: 500.000u
AMP & OFST changes to HIGH: 1.00000 LOW: -1.00000
MARK changes to   MPTS: 1
```

The menu fields and default values for the SINE WAVE MODE are as follows:

```
FREQ: 1.00000K   AMP: 1.00000    OFST: 0.00000
FILT=NONE        MARK: 0.00000   TRIG=FREE RUN
NOISE= ON        NAMP=0.00000    NBW=200 KHz
PHS = 0.00000    SYM =50.0000%
```

NOTE: FORMAT KEY CHANGES THE FOLLOWING FIELDS:

FREQ changes to PER: 1.00000m

AMP & OFST changes to HIGH: 1.00000 LOW: -1.00000

MARK changes to MPTS: 1

The menu fields and default values for the NOISE MODE are as follows:

```
NOISE=ON         NAMP=0.00000    NBW=200 KHz
```

The menu fields and default values for the TRIANGLE WAVE MODE are as follows:

```
FREQ: 1.00000K   AMP: 1.00000    OFST: 0.00000
FILT=NONE        MARK: 0.00000   TRIG=FREE RUN
NOISE= ON        NAMP=0.00000    NBW=200 KHz
DLY=0.00000      SYM =50.0000%
```

NOTE: FORMAT KEY CHANGES THE FOLLOWING FIELDS:

FREQ changes to PER: 1.00000m

DUTY changes to PLSW: 500.000u

AMP & OFST changes to HIGH: 1.00000 LOW: -1.00000

MARK changes to MPTS: 1

In the foregoing views of the Standard Function menu fields, the rectangle around the first two lines indicates the fields that initially appear in the two line active display area. The indicated lines roll up as the field select cursor is advanced beyond the current line end. For example, in the view that shows the SQUARE WAVE menu fields, when the cursor is stepped right to AMP and then to OFST and then to FILT the lines beginning with FILT and NOISE will occupy the two display lines available for viewing. The lines also wrap; that is, when the field select cursor is advanced past the last field, the first two lines will reappear.

FREQUENCY (FREQ:)

INTERNAL CLOCK:

Units: cycles per second (Hertz) are implied unless other prefix is specified
Minimum: 0.002
Maximum: 3.125 MHz (25 MHz clock rate model)
6.25 MHz (optional 100 MHz clock rate model)
Accuracy: The indicated frequency is within 0.01% of the actual
Resolution: Indicated frequency is within minus R.O.E, ±0.05% of requested value.

Round Of Error (R.O.E.): All Standard Functions (SFM) are computed by placing one cycle of the desired function into Output Memory (OMEM) utilizing the highest availabe Clock Rate. If the number or resultant waveform points exceeds the installed Output Memory size then the machine chooses a lower Clock Frequency to fit the function into OMEM. In this case the R.O.E. is negligable. An intergral number of solution points is, of course, required. That is, fractional memory locations are not available. The "2020" rounds-up to the next highest integral, which at a small number of points per waveform cycle will restrict the adjacent frequency selections more severly than the 0.05% clock rate resolution. For instance; in a 25 MHz version (40 ns minimum clock periods) if one selects 2 MHz in the SFM. The display will report 1.9230 MHz. Since at 2 MHz with a 40 ns Clock Rate 12.5 memory locations are required, the "2020" goes to 13 points which at the 40 ns clock yields the 1.9230 MHz, as shown on the display. If the ultimate (0.05%) frequency steps must be obtained at these higher frequencies, use the POLY mode. For example to yield a 2 MHz sine wave one would enter the following POLY expression:

FOR 500n SIN(2M*T) CLK = 38.451n

Note that 38.451 ns is the highest clock rate that results in an integral number (13) of data points per cycle. We could have specified CLK=35.714n to get 14 points, or CLK=33.333n for 15 points etc.

EXTERNAL CLOCK:

When CLOCK (CLK) is set to EXTERNAL (EXT) in the OP 2020 configuration mode, the display shows FREQ = EXT since the output frequency is a function of the external clock rate being used. Since the Maximum Memory (MAX MEM) value is used to describe one waveform cycle in the Standard Function Mode, the output frequency when using external clock is (MAX MEM) times the external clock frequency. The default MAX MEM value is 1000 and it can be changed in the OP 2020 configuration menu to any value within the range shown below:

	MAX MEM LOW LIMIT	MAX MEM HIGH LIMIT
25 MHz Version		
64K Output Memory	4	65535
128K Output Memory	8	131071
256K Output Memory	4	262143
512K Output Memory	8	524287
100 MHz Version		
128K Output Memory	16	131071
512K Output Memory	16	524287

TABLE BT-1

AMPLITUDE (AMP):
Units: Volts PEAK into 50Ω
PEAK-TO-PEAK (into 50Ω) will be two times indicated value
Unloaded output twice that expected into a 50Ω load
Maximum: −5V to +5V into 50Ω (±10V open ckt)
Minimum: −2.5 mV to +2.5 mV into 50Ω (±10 mV open ckt)
Accuracy: within ±10 mV ± 1% of indicated value
Resolution: ± 0.024% of amplitude setting

OFFSET (OFST:)
Units: Volts
Accuracy: ±10 mV ± 2% of indicated value
Resolution: 1.25 mv steps (into 50Ω)
Minimum: −5V into 50Ω (−10V open circuit)
Maximum: +5V into 50Ω (+10V open circuit)
Note: DC OFFSET is independent of the signal term; therefore, the value of dc offset does not alter the accuracy or resolution of the signal term to which the dc offset is applied. However, the combination of the signal term and the offset component cannot exceed the maximum output dynamic range of ±10V into 50Ω (±20V open circuit).

FILTER (FILT=)
Number: 10
Type: Passive (lumped Constant) modified Bessel, 3 Pole, low pass
Selectable 3 dB frequencies: 20 kHz, 50 kHz, 100 kHz, 200 kHz, 500 kHz, 1 MHz, 2 MHz, 5 MHz, 10 MHz, 20 MHz and NONE
Roll-off: 18 dB/Octave
Note: NONE results in the inherent output bandwidth which is 35 MHz minimum (50 MHz typical) which allows a 10 maximum (7.5 ns typical) rise time. Filter selection does not alter output impedance. The selection of a filter (except NONE) does have a slight impact on amplitude accuracy and, of course, affects amplitude flatness and settling time as expected due to the filters transfer function relative to the signal frequency spectrum.

MARKER TIME (MARK:)
Units: Seconds
Measured From: Leading edge of SYNC output pulse (rear panel, TTL)
Minimum: Zero (i.e., coincident with the SYNC output)
Maximum: 2 to the 22nd (approx. 4 million) waveform points times the clock period being used.

MARKER POINTS (MPTS:)
Units: Number of Waveform Data Points
In this alternate MARKER notation, the marker is set at a particular waveform point by counting data points.
Minimum: Zero data points (i.e., coincident with the SYNC output)

NOTES ON THE MARKER OUTPUT:
Output: Rear Panel; BNC connector
Level: Standard TTL with 10 TTL unit drive capability
Polarity: Positive leading edge
Duration: Returns to logical zero on next SYNC leading edge after expiration of MARKER time.
Note: DO NOT force any voltage (including zero) at the MARKER output

TRIGGER (TRIG =)
Input: Front panel; labeled "TRIGGER IN"
Allowable Input Voltage Range: −32V to +32V
Input Impedance: 1 MΩ (±10%)
Trigger Threshold Voltage: either zero or +1V; selected by set-up
configuration (OP 2020) as described in OPERATION CODES Section
of this manual.
Selections: FREE RUN, + START, −START, + GATED, −GATED, + STOP,
−STOP, + TO +, −TO −

FREE RUN Continuous output (not triggered or gated) with a SYNC out pulse at the start of each signal period.

+ START Triggered by the positive going TRIGGER IN transition, or by depressing the "MANUAL TRIG" key. Once triggered, the output is continuous.

−START Triggered by the negative going TRIGGER IN transition, or by depressing the "MANUAL TRIG" key. Once triggered, the output is continuous.

+ GATED Output Function is active WHILE Trigger Input voltage exceeds the trigger threshold, or WHILE the "MANUAL TRIG" key is held depressed.

−GATED Output Function is active WHILE Trigger In voltage is less than the trigger threshold voltage, or WHILE the "MANUAL TRIG" key is held depressed.

+ STOP Function output is active until a positive going TRIGGER IN transition is experienced, or until the "MANUAL TRIG" key is depressed. Output is started by "ENTER" "RUN" key sequence.

−STOP Output Function is active until a negative going TRIGGER IN transition is experienced, or until the "MANUAL TRIG" key is depressed. Output is started by "ENTER" "RUN" key sequence.

+ TO + Output Function STARTS on positive going TRIGGER IN edge and STOPS on next positive going TRIGGER IN edge or, starts on first depression of the ":MANUAL TRIG" key and stops on the next depression of the "MANUAL TRIG" key.

− TO − Output Function STARTS on negative going TRIGGER IN edge and STOPS on next negative going TRIGGER IN edge or, starts on the first depression of the "MANUAL TRIG" key and stops on the the next depression of the "MANUAL TRIG" key.

NOISE (NOISE =)
Selections: ON, HOLD
ON: Activates noise source and sums Noise Amplitude specified in the Noise Amplitude (NAMP) field with the signal being otherwise produced by the 2020. Note that the default state is NOISE = ON with NOISE AMPLITUDE = ZERO. Except when noise is being added to the signal (NOISE = ON and NAMP = > 0), the output signal uses a full 12-bit vertical resolution. In order to allow summing headroom in the output amplifier stage, the signal resolution is reduced when noise is added. Depending on the amplitude of the noise, the resultant signal resolution will be either 11, 10, 9 or 8 bits. HOLD: Holds OFF noise component OFF independent of Noise Amplitude (NAMP =) to allow viewing of signal component alone (without noise). With NOISE = HOLD the signal component is available (at the FUNCTION OUT connector with the inherent

resolution that it will have when the specified noise amplitude (NAMP =) is added; i.e., when NOISE is subsequently turned on. As discussed above the noise term requires a reduced signal resolution; therefore, NAMP should always be set to 0.00 unless the noise additive feature is required. Note that NAMP = >0 with NOISE = HOLD yields no additive noise but the output signal does not have its full potential vertical resolution of 12 bits.

Note: The internal noise source is hardware generated by a 32-bit psuedo-random, clocked at 16 MHz, with a 168 second repetition interval. The noise spectrum is therefore "Sin X over X" with line spacings of 0.0059 Hz with a first null at 16 MHz. From this spectrum, a uniform amplitude spectrum is obtained by application of one of the mandatory low pass filters that are described below (NBW =).

NOISE AMPLITUDE (NAMP =)

Units: Volts rms

In calculation of effective Signal to Noise ratio, the operator should take note of the fact that signal amplitude is expressed in volts PEAK and noise is expressed in volts rms

Minimum: Zero volts

Maximum: 2.7V rms. at 2 MHz noise bandwidth
0.95V rms. at 200 kHZ noise bandwidth
0.31V rms at 20 kHz noise bandwidth

NOISE BANDWIDTH (NBW =)

Selections: 2 MHz, 200 kHz, 20 kHz

Note: The amplitude distribution is Gaussian in all three filter bandwidths and without significant truncation except for the 2 MHz bandwidth case where amplitude clipping is imposed at about two sigma. The noise spectral density is 0.001768 V/root-Hz.

DELAY (DLY:)

Units: Seconds

Definition: Time from leading (positive) edge of SYNC output pulse to leading (positive) edge of SQUARE or PULSE wave at the FUNCTION OUT connector. In the case of TRIANGLE or SAWTOOTH modes, the DELAY time is measured to the center of the leading (positive) slope of the FUNCTION OUT.

Accuracy: Better than 0.01% of indicated value

PHASE (PHS:)

Units: Centicycle divided by 100

Range: 0 to 1

Definition: Phase shift from the leading (positive) edge of SYNC output to the positive zero crossing of the OUTPUT sinewave in decimal portions of a cycle. For example, 0.33333 would yield one third cycle (120 degrees) phase shift.

Accuracy and Resolution: ± one data point

DUTY CYCLE (DUTY:)

Units: Percent

Minimum Percentage: (clock period/waveform period) X 100

Maximum Percentage:((waveform period-clock period)/clock period) X 100

Accuracy: ± 0.01% or ± ((1/MAX MEM) X 100) whichever is greater

Resolution: ±0.05% or ±((1/MAX MEM) X 100) whichever is greater

Note: Clock period can be determined from examination of the RESTORE menu fields as described below. Waveform period can be determined by executing a "FORMAT" key toggle

when the (FREQ=) menu field is selected. MAX MEM can be examined or changed in the OP 2020 configuration routine (refer to OP Code Section).

PERIOD (PER:)

Units: Seconds

Minimum: 160 ns (100 MHz version)
160 ns (25 MHz version with 64K or 256K OMEM)
320 ns (25 MHz version with 128K or 512K OMEM)

Note: Minimum period is twice that given above if SYNC output is required.

Maximum: 687.173s times (MAX MEM). With MAX MEM set equal to installed output memory (OMEM), the resultant maximum period is 1.43 years for the 25 MHz version and 2.86 years for the 100 MHz version. With the 512K output memory option installed in either version, the maximum waveform period is 11.4 years. It is interesting to note that in all cases the maximum waveform period exceeds the warranty period.

Accuracy: ±0.01% of indicated value

Resolution: ±0.05%

Note: This field (PER=) is accessed by a "FORMAT" key toggle when the (FREQ=) field is selected.

PULSE WIDTH (PLSW:)

Units: seconds

Minimum: 100 MHz version:
10 ns or one (1) clock period, whichever is larger
25 MHz version:
40 ns or one (1) clock period, whichever is larger

Maximum: waveform period minus one (1) clock period

Note: Clock period can be examined in the (CLOCK=) field of the "RESTORE" menu list as described below.

Note: This field (PLSW=) is accessed by a "FORMAT" key toggle when the (DUTY=) field is selected in the SQUARE WAVE mode.

HIGH LEVEL (HIGH:)
LOW LEVEL (LOW:)

Units: Volts

Minimum: zero

Maximum: +5.0V (HIGH)
−5.0V (LOW)

Accuracy: Better than 1% of indicated value

Resolution: ± 0.025% of indicated value

Note: The HIGH/LOW fields are accessed by a "FORMAT" key toggle while either the (AMP=) or the (OFST=) field is selected in the SQUARE WAVE mode. This field nomenclature is useful when emulating logic level drive where the HIGH level specifies the positive or logic "1" level, and the LOW level specifies the negative or logic "0" voltage level.

SYMMETRY (SYM=)
Units: Percentage
Accuracy: ± 0.01% or ±((1/MAX MEM) X 100) whichever is greater
Resolution: ± 0.05% or ±((1/MAX MEM) X 100) whichever is greater
Note: Used in the SINE WAVE and TRIANGLE WAVE modes in the same manner as, and with the same characteristics as, DUTY CYCLE (DUTY=) in the SQUARE WAVE mode. If set to other than 50.0% in the SINE WAVE mode, an asymmetrical sine wave will be produced. If set to other than 50.0% in the TRIANGLE WAVE mode, the Triangle Wave will be unbalanced in the direction of a SAWTOOTH wave in that greater than 50.0% will yield a longer positive slope and proportionately shorter negative slope (frequency is maintained); and, less than 50.0% will yield the opposite. That is, a shorter positive slope and a longer negative slope.
Note: MAX MEM is examined or changed in the OP 2020 configuration routine (refer to the OP Code Section).

MODIFIED/RESTORE MENU FIELDS

This very useful feature is used to monitor waveform parameters and to modify them without having to recompute in either the Standard or Polynomial (arbitrary) function modes.
When the "RESTORE" key is depressed, the MODIFIED ☐ LED will light and nine (9) menu fields will appear on the display (six at a time). They are Clock (CLK=), Amplitude (AMP=), Offset (OFST=), Filter (FILT=), Marker (MARK=), Trigger (TRIG=), Noise (NOISE=), Noise Amplitude (NAMP=), and Noise Bandwidth (NBW=). All of these fields will contain the current value and/or attribute for the indicated menu parameters. They will all be familiar because you set them in the standard mode menu fields, except for Clock (CLK=). The value in the clock field reports to you the clock period (in seconds) that was used to synthesize the current output function. While in this MODIFIED mode, the output function is active (assuming R/S is in the RUN state) and unchanged unless one or more of the field values or attributes are changed. Field values or attributes are changed in the same manner as previously described for changing menu fields. When a field value or attribute is changed followed by depressing the "ENTER" key that parameter change is invoked and seen on the actual FUNCTION OUT, providing, of course, that the R/S mode is RUN. When the "RESTORE" key is again depressed, the MODIFIED ☐ LED will go out and all field parameters that were changed in the MODIFIED mode will revert to their original values.

When you invoke a change to the CLOCK PERIOD in the modified mode, you are changing the output clock period but not the clock period that was used to derive the function. Therefore, you will observe a FREQUENCY change of the FUNCTION OUT and not a change in horizontal resolution with the frequency fixed, as you might intuitively expect.

The clock rate (period) that the 2020 uses to derive the function is obtained by dividing the waveform period by the number of solution (waveform) points requested. If this quotient is less than the minimum clock period available (10 ns optional model, 40 ns standard model) then the minimum available clock period is used and the number of solution (waveform) points is correspondingly reduced. The requested number of waveform points is established in the configuration mode OP 2020, as described in the OPERATION MODES Section of this manual. The default value is 1000 points. The maximum number of waveform points that can be requested is

65535 (options at 131071, 262143, & 524287) for the 25 MHz version and, 131071 (optional 524287) on the 100 MHz version, whereas the minimum is 8 points on the 25 MHz version and 16 points on the 100 MHz version as well as on the 25 MHz version when optional expanded output memory is installed. The 8 and 16 point lower limits can be reduced further (4 and 8 respectively) if a SYNC output pulse is not required. In general, the higher the number of requested waveform points, the higher the resultant horizontal waveform resolution. However, the higher the number of requested waveform points the longer it takes to calculate a particular function be it a standard function or an arbitrary (polynomial) function as discussed in Section C of this manual. The default value is set to 1000 points by the MAX MEM field of the OP 2020 configuration routine.

Note: When NOISE = ON and NAMP is other than zero; or, when SUM IN is other than OFF the Amplitude (AMP =) field in the MODIFIED mode is not changeable. Additionally, none of the NOISE related fields (NOISE = , NAMP = , NBW =) are changeable in the MODIFIED mode.

SYNC OUT

Sync out is available on the rear panel as a standard TTL output drive which is normally logic "0" with a transition to logic "1" at the beginning of the waveform period (FUNCTION OUT). The sync pulse remains high for eight (8) clock periods in the standard memory (64K) 25 MHz version. In the 100 MHz version, and in the 25 MHz version with optional extended output memory, the sync output pulse remains high for 16 clock periods. If the waveform is constrained to less than that required for the sync pulse duration (8 or 16 data points as described above) the sync output will not be produced. The sync output is a TTL output drive which can be loaded only in accordance with standard TTL (10 unit load) practice.

OPERATION (OP) CODES:

OP CODES are used to implement and/or change system and I/O (input / output) configurations.

OP CODES are invoked by the key sequence "2nd" "OP" "x" "x" "x" "ENTER", where the x's indicate the OP Code number which will be four digits or less.

A listing of currently installed OP Codes in your machine can be obtained by executing the key sequence "2nd" "OP" "HELP". The display will then show you one particular OP CODE with a brief explanation of that Code and comment <more> in the lower righthand corner of the display. This means that depressing the "DOWN ARROW" will bring up another OP CODE and its explanation. When you get the last OP CODE listing, the display will inform you that the <ENTER> or <RESTORE> key should be used to EXIT this OP CODE HELP routine.

In the following OP CODE explanations, the phrase (optional) indicates that the particular OP CODE being described will be found in your machine only if the optional feature to which it relates has been installed. For example, if you do not have the RS232 I/O hardware option installed, OP 232 will not be found.

The following explanations show the screen display that you should expect to get when you call the OP CODE which shows the default parameters and values. Menu FIELD cursor selection, value changing, up line paging, etc., are all consistent with the editing explanations given in the STANDARD FUNCTION Section of this manual.

To change menu values or attributes: If there is a limited number of selections available for a particular menu field, the selection can be changed, or toggled between choices, by using either the "UP ARROW" or the "DOWN ARROW" cursor keys. In the case of a totally variable numerical value, as in Max Memory, simply enter the numeric value. A flashing value indicates that the change has not been entered, use the "ENTER" key to execute the new value. IMPORTANT: No menu field value or attribute changes are actually implemented until the "ENTER" key is depressed. This means that if you make a change and exit the OP CODE routine with the "RESTORE" key, **the change will not be realized** if you have failed to "ENTER" the new value.

OP 7

Op 7 is used to determine what, if any, optional features are installed. The key sequence [OP] [7] [ENTER] will bring to the screen a listing of all installed options. At the end of each option listing, the comment <more> means that the DOWN cursor key should be pressed to advance the listing. This routine will also report the amount of non-volatile RAM space available independent of whether the standard or extended RAM option is utilized. This available memory report is an indication of the remaining (unused) RAM space that can be used to store "poly" waveform descriptors. However, a small portion (less than 4K) of this reported space is reserved for segmented output memory operation in the direct data download mode (refer to the Remote Programming Section of this manual). The last line, of the options listing, contains the message "Press [RESTORE] to exit". This means that the [RESTORE] key will exit the OP 7 utility.

OP 232 (optional)

Op 232 is used to configure the RS232 I/O parameters. *IMPORTANT;* the two RS232 ports DCE (SER0) and DTE (SER1) have **independent** parameter configurations. To determine which port is being configured, you must examine and/or change the COMMAND (CMD) DEVICE field in the OP 2020 configuration to either SER0 or SER1. It is possible to configure **both** ports by going to OP 2020 and changing the CMD DEVICE field accordingly.

The display menu fields and default values for OP 232 are as follows:

```
BAUD RATE = 9600          STOP BITS = 1
PARITY  = OFF             DUPLEX  = FULL
LINE LENGTH = 80          TERMINATOR = <CR>
PROMPT = ON
```

BAUD RATE:
Selections: 110, 150, 300, 600, 1200, 2400, 4800, 9600, 19200

PARITY:
Selections: OFF, ODD, EVEN

STOP BITS:
Selections: 1, 2

DUPLEX:
Selections: FULL, HALF

LINE LENGTH:
Selections: 80, 132

TERMINATOR:
Selections: <CR>, <LF>, NULL

OP 488 (optional)
The display shows:

```
Bus address = 16              EOI out = ON
GET response = NONE           Talk SRQ = OFF
Listen SRQ = OFF              fast I/O = OFF
```

Bus address:

Range: 0 to 31

Definition: GPIB address assignment for this unit

Note: Reassignment of the Bus Address in this OP Code does not affect the next power-on default address that is determined by the rear panel switch assembly setting as described in figure AF-7.

GET response:

Selection: NONE, TRIGGER

Definition: GPIB "Group Execution Trigger"

NONE = "GET" not recognized

TRIGGER = Trigger previously loaded output memory at receipt of "GET"

EOI out:

Selections: ON, OFF

Definition: ON = "End Or Identify" word is expected on receipt and supplied on transmission.

OFF = "End Or Identify" word is optional on receipt and not supplied on transmission.

Talk SRQ:

Selection: OFF, ON

Definition: OFF = No "Service Request" sent in "Talk" mode

ON = "Service Request" is activated in "Talk" mode

Listen SRQ:

Selection: OFF, ON

Definition: OFF = "Service Request" not sent in "Listen" mode

ON = "Service Request" is sent when "2020" is ready to listen

Note: The Listen SRQ default is determined by the rear panel switch assembly shown in Figure AF - 7.

fast I/O:

Selection: OFF, ON

Definition: OFF = IEEE-488 communication speed is LOW (normal)

ON = IEEE-488 communication speed is HIGH

Note: This menu field is available only if the High Speed DMA option is installed.

When using either the RS232 or IEEE-488 communications a "**DEVICE TIMEOUT**" *message indicates that communications could not be established during a 5 second timeout period.*

OP 2020

The display shows:

MAX MEMORY = 1000	TRIG LEVEL = 1V
CLK SOURCE = INTERNAL	CLK LEVEL = 1V
IDLE VOLTAGE = 0V	DIGITAL OUT = OFF
MODE = NORMAL	CMD DEVICE = GPIB
MAX CLK = 100 MHz	

MAX MEMORY: (Change by keying in desired numeric value)

Range:

Minimum:

8 for 25 MHz with 64K or 256K output memory
16 for 25 MHz with 128K or 512K output memory
32 for 100 MHz version

Note: Minimum can be reduced to one-half the values shown above if an output SYNC pulse is not required.

Maximum: (either 25 MHz or 100 MHz versions)
65535 with 64K output memory
131071 with 128K output memory
262143 with 256K output memory
524287 with 512K output memory

Note: 64K and 256K are not available in the 100 MHz version.

Definition: Waveforms generated in the Standard Function Mode use this value to determine the number of horizontal datapoints per cycle for the waveform being generated. In the Polynomial (Arbitrary) mode, the number of horizontal datapoints in the output waveform will be this number or less. Less results when dc waveform portions are automatically compressed to reduce the output memory requirement. Increasing the "Max Memory" value results in higher horizontal resolution (finer grain waveform) at the cost of longer computation time.

TRIG LEVEL:

Selection: 1V, 0V

Definition: External Trigger Level Threshold in Volts

CLK SOURCE:

Selection: INTERNAL, EXTERNAL

Definition: Output Waveform Data Point Clock is derived either INTERNALLY or EXTERNALLY. " External Clock Input" is a BNC connector on the rear panel, so marked. Do not confuse this connector with the rear panel connector labeled "PLL (Phase Lock Loop) Reference Clock In".

CLK LEVEL:

Selection: 1V, 0V

Definition: External Clock Input Trigger Threshold in Volts. IDLE VOLTAGE: Selection: 0V, OPEN Definition: When the "RUN" □ LED INDICATOR is OFF, the output will be an active (driven) zero volts in the case of the 0V selection; or, an OPEN (floating) circuit in the case of the OPEN selection. The OPEN output configuration is useful for time-sharing the output line with other devices. When in the "float" state, do not apply more than ± 10 volts at the "Function Out" connector.

MODE:

Selections: NORMAL, MASTER, SLAVE

Definition:

NORMAL: This unit operates independently

MASTER: This unit is the MASTER for one or more (less than 3) other units. The other units are set to SLAVE mode. To operate in a MASTER/SLAVE mode, the following interconnections must be made between the MASTER and its SLAVE units, with coaxial (BNC connector) cables not to exceed 20 feet:

1. PLL REFERENCE CLOCK OUT ON MASTER TO:
   PLL REFERENCE CLOCK IN ON SLAVE UNITS
2. GATE OUT ON MASTER TO:
   GATE IN ON SLAVE UNITS.

In the MASTER/SLAVE MODE triggering or gating of the MASTER will automatically cause the SLAVES to trigger or gate accordingly. Additionally, the data point clock of the SLAVE/s will be Phase Locked to the MASTER. Due to interunit cable delays there will be a time offset in the trigger or gate time on the SLAVE, relative to the MASTER. This delay can be trimmed to be very near zero by means of the rear panel screwdriver adjustment labeled "Trig dly"; in the MASTER/SLAVE modes, the data point clocks are phase locked to each other. However, there could be a phase offset of up to 20 ns which can be adjusted very near to zero by means of the rear panel screwdriver adjustment labeled "clk dly".

DIGITAL OUT: (optional on 100 MHz model, Standard on 25 MHz model)

Selections: OFF, ON

Definition: Activates (ON) or Deactivates (OFF) the rear panel Digital Output Data Word. This digital data is 16 bits with clock (positive edge). The most significant 12 bits of this data relate to the simultaneous analog output (Function Out) waveform. In the case that the waveform output memory was externally loaded, the digital data out is a straightforward replay of that data. However, if the waveform output memory was internally loaded, by either a Standard Function or a polynomial computation, there are a few particulars that the operator should bear in mind. In the case of internal generation, dc offset is stripped from the digital data. That is, only the ac (zero average) data is retained. Also, the data is always full scale, over the digital word range regardless of actual analog output amplitude value. If external SUM IN or internal NOISE is activated, however, the digital range is less than full scale by an amount that is inversely proportional to the amplitude of the noise and/or external Sum In amplitude even though neither the noise or external sum signal is contained in the digital output data. The form of this digital data when internally generated, is offset binary where 8000 Hex is zero, FFFF is positive full scale, and 0001 is negative full scale.

The digital Output Data is standard TTL level compatible in the standard 25 MHz model of the 2020. On the optional 100 MHz model 2020, the output type is ECL.

MAX CLK:

Selection: 100 MHz Version; 25 MHz, 100 MHz
25 MHz Version; fixed at 25 MHz (no selection allowed)

Definition: Selecting [25 MHz] on the 100 MHz option model will reconfigure the "2020" to act as a standard 25 MHz version. This is particularly useful to avoid the multiple of 16 data point requirement when operating a 100 MHz version in the arbitrary (polynomial) or Data Down Load modes.

CMD DEVICE:

Selection: GPIB, SER0, SER1, NONE

Definition: This menu selection determines the I/O Command Device. If neither the GPIB (IEEE-488) or the RS232 options are installed this field will indicate "NONE" and you will not be able to toggle to the other indicated selections. If only GPIB is installed, the field selections will be GPIB and NONE. If only RS232 is installed, the field selections will be SER0, SER1, and NONE. If the rear panel switch selectors are set to a default which corresponds to a non-installed option, the system will choose, as a default an I/O option that is installed. Otherwise, the rear panel selector switch assembly determines the default CMD Device selection. Refer to figure AF - 7 for further clarification on the rear panel selector switch assembly.

OP 6000:
The display shows:

DATA 6000 bus address = 15
Step to correct address then <ENTER>

1

Reading Directory - - -
Step to desired file then <ENTER> .

2

device timeout

3

In the first display window, the 2020 is asking the operator to confirm that the Data 6000 Waveform Analyzer has a GPIB Bus Address of 15. If not, the correct Data 6000 Address is entered by stepping up or down with the "UP" or "DOWN cursor keys (range 00 thru 31). In either case, <ENTER> results in the second display which indicates that the 2020 is establishing communications and reading the Data 6000 File Directory. If communications with the Data 6000 cannot be established (within 5 seconds), the third display (device timeout) will appear. Assuming that communications with the DATA 6000 are established, the display will then show the directory contents of the D6000. The first file name will be flashing (selected). The <ENTER> key will indicate to the "2020" that this flashing file is to be downloaded to the 2020 for subsequent analog replication and outputting. If that is not the file you want, change the "flashing" selection with the CURSOR arrow keys. The "Left" and "Right" keys will step the selection left and right respectively. The "Up" and "Down" keys cause the selection field to change Up or Down in the directory lines. If there are more file names than can be contained on the two display lines, automatic line paging will occur so that you can scroll through the entire D6000 directory. A typical display showing the downloaded D6000 directory listing would be as shown in the following fourth display view:

BUF.A1	BUF.A2	BUF.A3	MAGCA1
AVEGCA2	DIFFA3		

4

When the Data 6000 directory selection has been executed by depressing the [ENTER] key, the selected file will be passed to the "2020". While this file transfer is taking place, the display will appear as shown below in step 5:

```
Reading File ...
Please wait
```

5

```
BUF.A1 Endpoint = 12545
Press <ENTER> or <RESTORE> to EXIT
```

6

In the sixth display view (above), the 2020 has downloaded the Data 6000 waveform file name BUF.A1 containing 12545 data points in this example. At this point, the number of data points to be reproduced by the 2020 can be reduced by changing the END POINT = number before executing the reconstruction <ENTER>. This truncation of the waveform end point may be desired if, for instance, the downloaded waveform is not an even multiple of periods and a continuous (free run) 2020 output is desired with no wrap-around discontinuity.

To change the waveform end point after execution has been initiated use OP 6001.

OP 6001:

Range: Maximum = number of points originally downloaded with OP 6000
Minimum: 8 for 25 MHz with 64K or 256K output memory
16 for 25 MHz with 128K or 512K output memory
32 for 100 MHz version
Note: Minimum can be reduced to one-half the values shown above if an output SYNC pulse is not required.
Maximum: (either 25 MHz or 100 MHz versions)
65535 with 64K output memory
131071 with 128K output memory
262143 with 256K output memory
524287 with 512K output memory
Note: 64K and 256K are not available in the 100 MHz version.
Definition: Provides a means to truncate waveform end point.

OP 9999:

Definition: Used to delete entire contents of 2020 non-volatile memory. The Internal Directory of the 2020 is further described in Section D of this manual where selective file deletions are explained. In general, files should be individually deleted rather than using this (OP 9999) bulk erase method.

This bulk erase operation does not effect the portion of non-volatile RAM that is reserved for segmented output memory control. This reserved memory is further described in OP 7 of this Section and in the Remote Programming Section of this manual.

If directory difficulties are experienced due to having lost battery back-up power, or due to the installation of the extended RAM memory option to a unit that had previously been operating with standard RAM; this bulk erase (OP 9999) routine should always be used to reinitialize and reallocate the RAM space.

When invoked, by pressing [ENTER], the display shows:

```
This will delete all files saved in non-volatile RAM
Do you want to continue ? <YES> or <NO>
```

If complete erasure is your intention, depress the [YES] key; otherwise escape by pressing [NO].

FACTORY DIAGNOSTIC CODES:

There are other OP CODES that are reserved for Factory Diagnostic routines that are used during the manufacturing cycle. These OP Codes are not described here and are mentioned only in the event that an erroneous entry of an intended OP Code yields something that is not recognizable to the operator. In this case abort the extraneous OP Code by "RESTORE".

NOTES:

POLYNOMIAL (ARBITRARY WAVEFORM) MODE:

In this mode, the "2020" acts as an ARB (Arbitrary Waveform Generator) utilizing a waveform descriptor language that is arbitrary, universal, and inherently understandable. That language is Algebra. In this mode the 2020 can be likened to a Video Calculator on which your time domain expression in the form Y = f(t) is evaluated and generated as a voltage function of time V = f(t). This mode provides a very powerful method for the generation of essentially any waveform that the operator may require and it represents the essence of the "2020" versatility.

TO ENTER THE "POLY" MODE:

If the 2020 is in any of the STANDARD FUNCTION MODES (SFM), depress the key for the current SFM. The SFM light will go out and a blinking cursor will appear in the upper left corner of the display, indicating that you are now in the POLY MODE. On initial power-up (turn-on), the unit is in the POLY MODE even though a sign on message is on the display. The sign on message will be removed upon the first key press in the POLY MODE or you can intentionally remove it by depressing any of the Cursor Arrow keys at which time you will see the flashing cursor.

AN EXAMPLE:

Let's do a quick and simple example to get started. The algebraic form of a sinusoidal waveform is V = a X (sin w X t + theta) where V is the instantaneous output voltage, [w] is the angular rate, [a] is the amplitude coefficient, [t] is time on the horizontal axis (starting at zero), and [theta] is the phase offset.

CYC/RAD MODE:

For trigonometric arguments, the 2020 accepts either radians (RAD) or Cycles Per Second (CYC). The default (power-on) mode is CYC. When the CYC indicator is lit trigonometric angular rates (w) is in Cycles Per Second and phase offset (theta) is in cycles, i.e., 0.25 cycles relates to 90 degrees. When in the RAD mode (RAD indicator lit) angular rate (w) and phase offset (theta), are both in radians. The CYC/RAD mode must be properly selected before the {ENTER} key is depressed. Unless otherwise specified, the CYC mode will be assumed throughout this section.

EXAMPLE CONTINUATION:

To make this quick example even simpler, let's assume 1 (unity) for the amplitude coefficient and zero for theta with a 1 kHz frequency.

1. Turn on the "2020" and observe a short diagnostic routine (all LED's and display segments lit) followed by a sign-on message. Or, if the unit is already on and in a SFM mode, for example, Square Wave, depress the SFM key (in this case [Square Wave]) to exit SFM and enter the POLY mode. A blinking cursor in the left most display position is your indication that you are in the POLY mode.

2. Execute the following KEY SEQUENCE: [FOR] [1] [2nd] [m] [space] [SIN] [1] [2nd] [K] [X] [T] [)]

3. Observe on the display: "FOR 1m SIN(1K*T)" which means, do for 1 ms the sine of 1 kHz. At this time you have probably made some observations. The engineering notation milli [m], micro [μ], kilo [k], etc. do not imply dimensions such as volts or seconds. Rather, the dimensions are understood on the "2020" by virtue of their location within the expression. In this case, milli [m] is taken as milliseconds and kilo [k] is taken as kilocycles. The left parenthesis after SIN was automatically inserted. The [space] is optional in that it only provides a more readable expression upon viewing the display. And we started with an evaluation time, in this case 1 ms.

4. Connect the SYNC OUT on the "2020" to trigger a dual trace oscilloscope and arrange the scope so that you can observe this trigger signal (2020 SYNC) out on one of the traces. Connect the "2020" Function Out to the Vertical input of the oscilloscope, through the 50Ω terminator (supplied with the 2020) with appropriately set vertical and horizontal scale factors to observe a 1 kHz sine wave on the other scope trace. Note that the sine wave is not yet being generated by the "2020".

5. Now back to the 2020. Press the [ENTER] key and note that the display says "computing 1000 points" (the default horizontal memory length is 1000 points, see the OP 2020 command in the OP CODE Section if you wish to change the number of data points to be computed). Depress the [R/S] key and note that the RUN indicator lights.

6. Observe a 1 kHz sine wave of 1V peak amplitude on the oscilloscope. You will also note that the zero crossing (zero phase) is coincident with the positive edge of the SYNC OUT pulse and that the waveform is continuous even though we had specified 1 ms. This is because the default 2020 triggering mode is FREE RUN so that the specified 1 ms is being repeated, continuously. Other triggering modes will be discussed under TRIGGERING and in the SFM Sections of this manual.

EDITING:

Text editing is easy. Let's now change the simple 1 kHz sine wave expression to yield a 45 degree theta (1/8 cycle starting point) and change the amplitude to 1.5 Vp. We could clear the entire display with the key strokes [2nd] [CLR] and re-key the entire expression; but for the sake of editing practice let's change the previous expression, which should still be on the display as {FOR 1m SIN(1K*T)} followed by a blinking cursor.

1. Use the LEFT ARROW to step the cursor left until it is under the S in SIN. Now key in [1] [.] [5] [X] [(] and note that the display now shows: "FOR lm 1.5*(SIN(1K*T)".

2. Now move the cursor to the right (with the RIGHT ARROW key) until it is under the right parenthesis [)] and key in [+] [.125] and note that the display now shows: "FOR 1m 1.5*(SIN(1K*T+.125)" followed by a blinking cursor at which point we need a right parenthesis. But before we give it the parenthesis, let's depress the [ENTER] key. Note that the display says '*missing*)' to indicate that the expression is not acceptable and that a missing right parenthesis is the most *probable* cause. Since the cursor is at the proper place to insert the missing parenthesis, now key [)] and observe that the display shows: "FOR 1m 1.5*(SIN(1K*T+.125))". At this time, the RUN light is still on and the Function Out is still the previous 1 kHz waveform example.

3. Now press [ENTER] and observe the {computing 1000 points} message followed by the appearance of our revised Function Out on the oscilloscope. You will now note that the starting phase is 45 degrees (0.125 cycles) with a new amplitude of 1.5 Vp or 3.0 Vp-p into 50Ω. If your load is other than 50Ω, the amplitude will not be what you expect, for example if the load impedance is very high compared to 50Ω the output voltage will be twice the expected value.

4. To continue the editing example, note that the outer parentheses pair in the foregoing example are actually not necessary. Practice deleting the outer parentheses pair and re-enter. After doing this, you should see the same output waveform. Now try taking out the 0.125 cycle offset and re-enter.

DIRECTORY: (Store [STO], Recall [RCL] and Delete [DEL])

If you would like to store the example expression for future recall you simply give it a name before it is entered. The name must begin with an ALPHA character and be less than nine characters long followed by an equal sign. Let's name this one F33. To do this, we edit the display to read:

"F33 = FOR 1m SIN(1K*T)", now press [ENTER]. Or, instead of editing to affix the file name we could have keyed in [STO] [F] [3] [3] [ENTER]. The waveform is recomputed and reappears at the Function Out, but this time, it has been stored in permanent (non-volatile) memory. To verify this, turn the 2020 power OFF and back ON. Now depress the directory key [DIR]. There will be one or more expression names on the display, one of which will be F33, and one of them will be flashing. If F33 is not the flashing one, press either the LEFT or RIGHT (UP/DOWN to jump directory lines) until F33 is selected (flashing). Now depress the recall [RCL] key. You will note that your expression is recalled to the display. If you activate RUN and press [ENTER] you will regenerate the F33 function.

There are two methods to DELETE an expression. In the first, press [DIR], select (cause to flash) the desired expression name and press delete [DEL]. Try this without F33. Verify that you have deleted it by pressing directory [DIR] and noting that it is no longer listed. Now key in our sample expression and name it F34, [ENTER] it and press [DIR] to verify that it has been stored. Now delete it by the second method which is simply the key sequence [DEL] [F] [3] [4]. As in the previous deletion method the display will ask if you "are sure ?". If you recall an expression by file name, and change it in any way followed by [ENTER] in order to execute the changed expression, the display will ask if you wish to replace the old expression with the new since you now have two expressions with the same name. If you do not wish to overwrite the previous expression, either change the name of the modified one or remove its name. Remember, an expression with no name can be executed, but it is not automatically stored. You can construct alpha sequences to form mnemonics or words as file names by pressing keys as LOG, SIN, TAN, etc., and editing out characters with the [CE] key. Of course, over the remote control bus you can dictate alphanumeric strings with the previously mentioned constraint. That is, the first character must be ALPHA and you cannot have more than eight characters total. To erase the entire memory (delete all files) refer to OP 9999 in the OP CODE Section of this manual.

EXPRESSION AND DIRECTORY SIZE:

An executable expression can contain up to 520 display character locations, which includes file name, spaces, attributes and all other characters that occupy a display location. Note that the display shows up to 80 of these characters at a time with auto scrolling to view the rest. The non-volatile memory can store up to 30K bytes (with an additional 48K bytes available by option). Each file (expression) requires 20 bytes of directory overhead and each display character requires one byte. Therefore, to store one expression containing 30 display characters we would occupy 50 bytes of non-volatile memory. Note that there is no limit to the number of files (expressions); except that the directory overhead (20 bytes/file) would occupy all of the 30K available spaceJat 1500 files in the standard unit (3900 in the optional expanded non-volatile memory). In realistic terms, considering an average file (expression) length to be 60 characters, the number of stored expressions could be up to 375 in the standard memory and up to 975 with the optional extended memory. Note that some (up to 4K) of the remaining, unused, RAM reported in OP 7 and in the external Directory Dump must be reserved for segmented memory operation, whether or not such segmentation is being used (refer to the Remote Programming Section).

MEMORY AND FILE TYPES:

The "2020" has three (3) separate and distinct memory banks:

1. Non-Volatile RAM for storage of POLY expressions as described above and for internal CPU variable and stack space. The user's portion of this memory space is 30K standard and 70K optional.
2. Output Memory (OMEM) volatile RAM. This is the memory space that contains the waveform datapoints that are to be used in creating the analog and/or digitial waveform. The standard size of memory is 64K and 128K on the 25 MHz and 100 MHz versions respectively. It can be optionally expanded to 512K data points on the 100 MHz version, and there are 128K, 256K and 512K options available on the 25 MHz version.

The output memory is 15 bits deep even though only the top 12 bits are used for analog waveform generation.

3. Memory Controller: The high speed state-machine that controls the addressing of Output Memory utilizes a 4K by 32 bit memory. This memory is not accessible by the user.

In the foregoing discussion on Directory Store [STO], Recall [RCL] and Delete [DEL] we were dealing with the Non-Volatile (type 1 above) memory. Files (waveforms) can also be stored in Output Memory (type 2 above) and manipulated with the same commands, Recall [RCL] and Delete [DEL] commands. OMEM files are, however, not stored with the Store [STO] command. They are created and stored either by direct data download (ref Remote Programming Section) and they are automatically created and named as a result of the last waveform that resided in OMEM. OMEM files can be distinguished from normal (non-volatile) files in that they are appended with a dot (.). An automatically created OMEM file will purge all other, previous, OMEM files.

When you exit the SFM mode a file will be created that is named "STDFN"; and when you exit the POLY mode a file named "POLY." will be created. These files ("STDFN." & "POLY.") can be recalled [RCL] and RUN. An unnamed Data Downloaded file will also be automatically named as "DATA." and will also purge the previous OMEM files. However, named Downloaded Data files will not purge. They will be appended to preexisting OMEM files, including automatically created ones, and can be selectively Recalled. Since OMEM files do not have to be computed (they already exist in direct waveform data point form) they can be rapidly (less than 25 ms) recalled for sequential waveform switching. This is particularly useful in a remote control test environment and is further described in the Remote Programming Section of this manual.

MODIFY/RESTORE:

Certain output waveform parameters can be varied, in real time, without having to either change or recompute the expression. These are Data Out Clock (produces an output waveform *frequency* change), Amplitude (unless NOISE feature is in use), Offset, Filter, Marker Time, and Trigger Mode (except in POLY Mode). Depressing the [RESTORE] key lights the "MODIFIED" indicator and brings the parameter fields to the display for either verification of current values and status or to allow operator change of a selected parameter. The parameter is selected and changed in a manner that is identical with that described in the Standard Function Mode (SFM) Section of this manual. If the menu field parameter will not change , a parameter change is not allowable under the particular set-up that you are using. To reiterate some of the material discussed in the SFM section:

1. Any and all parameters changes automatically revert to the original values when the "MODIFIED" mode is exited by depressing [RESTORE].

2. Changing CLOCK period or frequency affects only the clock rate that is used to output the data points and not the clock rate used to evaluate the expression; therefore, changing the clock rate produces a frequency change in the waveform and does not change its horizontal resolution.

3. If a requested value is automatically changed on the display that (changed) value is the closest to the requested value that is achievable.

4. If no parameter changes are desired this ("MODIFIED") mode is useful for determining the clock value that was selected by the 2020 when it evaluated the expression.

The 2020 will use a higher evaluation clock rate (greater horizontal resolution), providing that its upper rate capability is not exceeded, if the operator were to request a greater number of solution points in the OP 2020 configuration set-up (refer to OP Codes Section of this manual).

DIRECTIVE STATEMENTS:

Directive statements are used to control and direct the horizontal dimensions of your waveform.

"FOR" DIRECTIVE *and* THE VARIABLE (T) Vs THE VARIABLE (t):

[FOR] Directive

The "FOR" directive is of the form FOR {Time} {expression}; and it means evaluate the expression for the time duration. Let's use the FOR directive in a few typical statements. FOR 2.2m SIN(1000 *T) will generate 2.2 cycles of a 1 kHz waveform (assuming CYC mode) since the specified evaluation time of 2.2 ms (note that seconds are implied) yields 2.2 periods at the specified frequency. FOR 5 1 produces a 1V level for 5 seconds. Note that the second, again, is implied and that the expression in this case is simply the number 1 which is separated from the time argument (5 seconds) by a space. FOR directives can be concatenated; that is, the multiple statement FOR .25m 1 FOR 500μ COS(1K*t) FOR .25m −1 will produce an output waveform that is +1V for 0.25 ms followed by one half cycle (0.5 ms) at 1 kHz with a peak amplitude of 1V (times 1 is assumed as the coefficient for the trig term) followed by −1V for .25 ms. Since we used Cosine and small t to express time the trig term started at 90 degrees and since its run time was 1/2 a cycle it ended at 270 degrees. The use of small or large T to express the variable (time) will be discussed below. It is imperative that a space be left in front of each successive FOR statement to delineate it from the previous one as shown in the foregoing example. Try this multiple FOR statement for drill. The result should be as shown in Figure 1.

(T) Variable Vs (t) Variable: "2020" expressions can contain either no variables or the variable time. The variable time has two notation methods (T or t). Large "T" is the cumulative time from the beginning of the expression (starts coincident with the sync out pulse) to the end of the expression (start of the next sync pulse or the end of the waveform depending on trigger mode). Small "t" is also cumulative but it resets to zero when first encountered and adds to large "T". Each time that a new FOR statement is encountered small "t" begins at zero but large "T" is continuous and non-resettable. There are further considerations to the relation of "T" and "t" that will be elaborated upon in the REPEAT (RPT) directive discussion which follows, in this Section. Figures 1 & 2 illustrate the effect obtained relative to the use of large "T" or small "t" with both expressions being otherwise identical. In figure 1, we used small "t" so that when the second FOR directive was encountered the first data point was taken as Cosine of zero degrees, or +1V, which corresponded to the value of the last data point in the first FOR directive, also 1V. Whereas, in Figure 2 we used large "T" so that when the second FOR directive was started "T" was at a value of 0.25 ms (1/4 cycle at 1 kHz) and the first data point in the second FOR section was Cosine 90 degrees, or 0V.

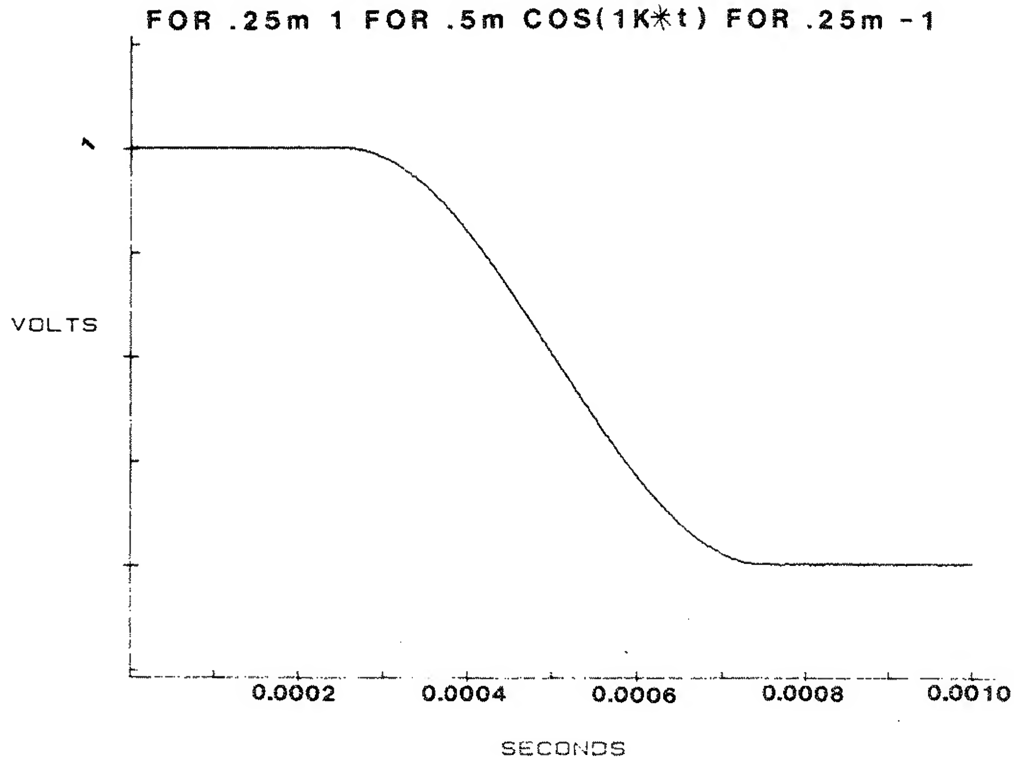


FIGURE 1

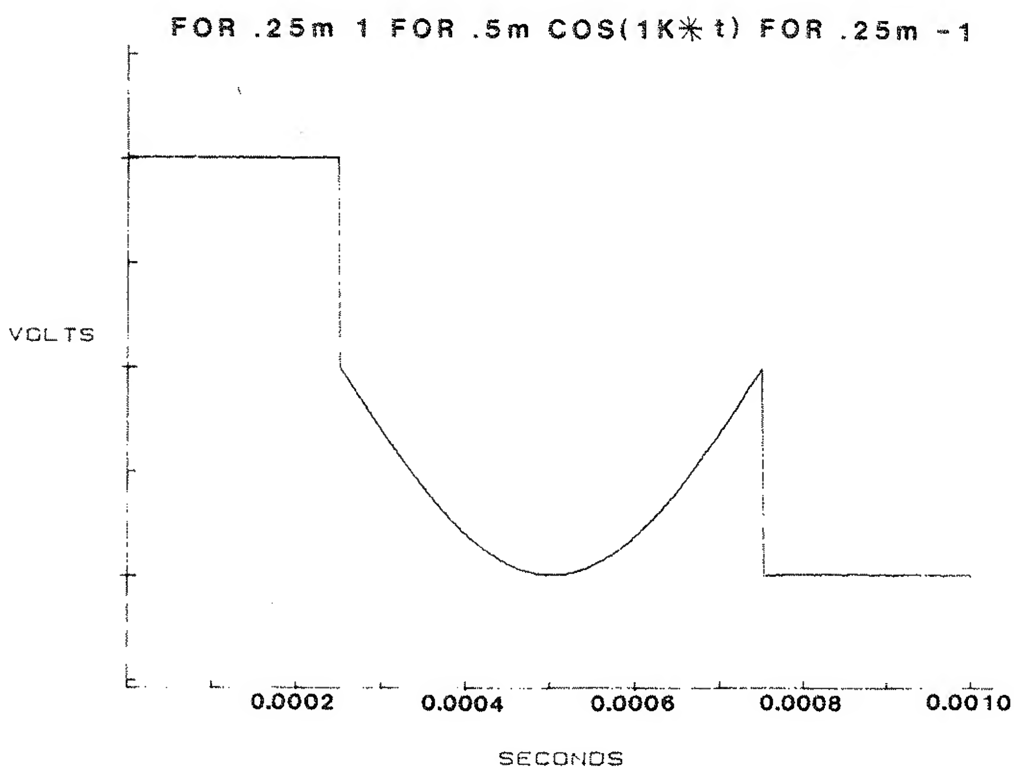


FIGURE 2

"TO" Directive:

The "TO" statement uses the format TO {time} {constant} which causes the constant (dc voltage value) to exist from the statement start time up and TO the specified time {time}. The statement start time is the current value of large "T" which is zero if this is the first statement. For example, the statement F22= TO 10.2m 3.574 would provide a dc value of 3.574V from zero time to 10.2 ms, and since we named it, the expression will be stored under the file name F22. "TO" statements can be concatenated. For example, "TO 1 1 TO 2 2 TO 3 3 TO 4 4" would produce a three step voltage staircase composed of one second steps wherein the first level (step) is 1V, the second 2V, etc. Note that as in the case of FOR statementsJa space is required to separate the time from the voltage value and to delineate between successive TO statements.

"AT" Directive:

The format for the "AT" directive is AT {time} {voltage}. This is similar to the "TO" statement except that a voltage ramp is formed such that the specified {voltage} is achieved at the terminal end, specified {time} of the linear ramp whose starting voltage value is whatever existed at the beginning of the "AT" statement. For example, "TO 1m 0 AT 2m 3 AT 4m – 1" would produce a waveform that is 0V from zero time to 1 ms which then ramps to +3V at T = 2 msJat which time it reverses slope and ramps to reach – 1V at T = 4 ms. You should think of "TO" as a voltage step whereas "AT" is a voltage ramp. From this example, it is obvious that "AT" statements can also be strung together and that they can be combined with "TO" statements. Actually, "FOR" statements can also be included.

MIXED DIRECTIVES ("AT", "TO", "FOR"):

Figure 3 shows a complex waveform that is constructed with four "AT", five "TO" and three "FOR" statements. This construction should be self-evident if the "2020" expression is compared to the waveform for each directive taken separately.

REPEAT ("RPT") Directive:

The Repeat [RPT] directive can be used to loopJon arbitrary sequences of FOR, AT, and TO segments which we will refer to as "FAT" sequences in the following definitions. This is a very powerful operation that allows the generation of output waveforms that appear to be composed of substantially more data points than that which the Output Memory can support. In addition to this directed RPT an invisible form of REPEAT is automatically invoked in the POLY mode to compress the amount of Output Memory required when a dc term is encountered in a waveform.

To specify a repeated sequence n times, enter:

    . . . . RPT n (FAT sequence) . . . .

An example of such a single repeat statement is shown in Figure 18 where one cycle of a 1 kHz sine wave is repeated twice. If the RPT encloses the entire equation, as in this example, then the "2020" will repeat the entire equation n times, and stop (FUNCTION OUT will remain at the voltage of the last point in the equation). The "2020" can, in this manner, generate single or multiple shot arbitrary waveforms by entering RPT n (FAT sequence).

A single level of nested repeats may be used to generate multiple shot waveforms which contain repeated sequences by entering:

    RPT n (. . . . RPT n (FAT sequence) . . . .)

An example of this is shown in Figure 19 where the inner repeat loop generates two (2) cycles of a 1 kHz Cosine wave; this inner loop is preceded by a 1 ms ramp. So, the outer loop repeats two (2) times the combination of the ramp and the two cycles of Cosine wave. Note that after the outer loop finishes, we encounter the directive "AT 3m 0"; this forces a zero at 3 ms and for all time after. From the waveform shown in Figure 19 you can see that this zero voltage was forced at 8 ms into the waveform which seems to contradict the 3 ms directive. This is because looping time is not counted in the determination of AT and TO directives. In the example, it can be seen that the

1 ms after the FOR directive and the 1 ms after the first AT directive were the only sections that expensed actual output memory space before the last AT directive was encountered. Therefore, the actual memory time when the last AT directive was encountered was 2 ms instead of the output function virtual time of 7 ms.

The following "POLY" constructions are shown in Figures 20 and 21, respectively:

F20 = RPT 2 (FOR .1m 1 FOR .4m T/.4m FOR 1m SIN (1K * T)) TO 3m .5

F21 = RPT 2 (FOR .1m 1 FOR .4m t/.4m FOR 1m SIN (1K * t)) TO 3m .5

Even though these waveform descriptions appear to be the same, examination of figures 20 and 21 will illustrate that they are quite different. The difference lies in the use of absolute time (large "t") in the first and relative time (small "t") in the second. Absolute "T" enters the repeated sequence at the current absolute time, and is incremented through the sequence to calculate a set of data points representing the sequence; this set of data is repeated "n" times. The value of "T" when leaving a repeated sequence is equal to the time when it was entered plus the length of the repeated sequence (not multiplied n times). For example, the waveform labeled F20 (shown above) will produce a waveform repeated two times consisting of a 0.1 ms 1V step followed by a 0.4 ms ramp going from 0.25V to 1.25V followed by 1 cycle of a sine wave that is 180 degrees out of phase. Then the waveform will step to 0.5V for 1.5 ms (4.5 ms after SYNC). Finally, this entire sequence will repeat continuously.

The relative time "t" is reset at the start of each segment within a repeated sequence just as in non-repeated segments. For example, the waveform labeled F21 (shown above) will produce a waveform repeated two times consisting of a 0.1 ms 1V step followed by a 0.4 ms ramp going from 0.0V to 1.0V followed by 1 cycle of a sine wave with zero phase offset. Then, the waveform will step to 0.5V for 1.5 ms (4.5 ms after SYNC). Finally, this entire sequence will repeat continuously. Refer to Figures 20 and 21 for a clear pictorial view of the distinction between large and small time variables (T, t) when encountered in REPEAT statements.

REPEAT RESTRICTIONS:

There are four "ground rules" that should be understood when using the Repeat (RPT) directive:

1. Sequences may be repeated a minimum of 1 and a maximum of 65535 times. Repeats may be strung sequentially in a single equation.

2. There is a minimum number of points required in each repeated sequence which depends on the hardware configuration and the MAX CLK selection (OP 2020 configuration set-up menu). 25 MHz systems with either 64K or 256K installed Output Memory require 4 data points minimum. 25 MHz systems with other Output Memory options require 8 data points minimum. 100 MHz systems require 16 data points minimum unless MAX CLK is set to 25 MHz in which case, the minimum is 8 data points.

3. Systems running the 100 MHz mode require that each repeated sequence must be a multiple of 16 points long. The generator will automatically fill in the necessary number of points in each repeat sequence to satisfy this minimum requirement. However, this auto-fill may not be acceptable with regard to the intent of your output waveform in which case you must design your function such that the segment duration is divisible by a 16 times multiple of the clock rate. Note that the generator will automatically choose the Clock Rate but this can be overriden by a user specified Clock Rate (refer to POLY mode Modifiers in this Section).

4. In systems running in the 100 MHz mode, nested repeats which have the inner repeat end at the same time as the outer one may not work for clock rates faster than 15 ns due to hardware limitations. If this condition exists, a warning message will be displayed.

REPEAT AND THE SYNC OUTPUT:

SYNC will go active each time that the equation starts. When repeating an equation "n" times, "n" SYNCs will be generated. Segment repeats will have no effect on the SYNC. That is, additional SYNC transitions will not be produced on REPEATS that do not involve the outer equation loop.

TRIGGER CONSIDERATIONS WHEN USING REPEAT:

Triggering modes with RPT are essentially the same as for general POLY mode with particular consideration to the RPT function as described below:

FREE RUN
Equation output will start when the computer has finished computing. It will run "n" times, and then stop at the last programmed data point. To restart the function (equation) output, RUN/STOP must be toggled.

AT ± TRIG or ± START
Signal output will start at the next active trigger edge and will run "n" times until complete. The next trigger edge will restart the output. Trigger edges occurring while outputting an equation will be ignored (the "2020" is not retriggerable). There is a minimum dead time of 0.5 μs from equation end until a trigger edge is accepted.

TO ± TRIG or ± STOP
Signal output will start when the computer has finished computing. The signal will stop after it has either run "n" times to completion, or an active trigger edge has been detected. Subsequent triggers will have no effect because the output has already stopped. To restart the function output, RUN/STOP must be toggled.

AT ± TRIG, TO ± TRIG, or ± TO ±
Signal output will begin at an active trigger edge, and will stop after it has either run "n" times to completion, or until a trigger edge has been received. The next trigger edge will restart the signal.

FOR ± TRIG, or ± GATE
In the gated mode, the output signal will remain active while the trigger input is active or until the equation has run to completion. The output will stop when the gate goes inactive, and will restart when it goes active again.

POLY MODE TRIGGERING:

The basic "2020" triggering modes are described in the Standard Function Mode (SFM) of this manual. For POLY mode operation, you must set the trigger mode in a different manner and the trigger mode nomenclature is changed as follows:

SFM MODE	POLYNOMIAL MODE
+ START	AT + TRIG (or AT TRIG)
−START	AT −TRIG
+ GATED	FOR + TRIG (or FOR TRIG)
−GATED	FOR −TRIG
+ STOP	TO + TRIG (or TO + TRIG)
−STOP	TO −TRIG
+ TO +	AT + TRIG TO + TRIG (or AT TRIG TO TRIG)
−TO −	AT −TRIG TO −TRIG

As in the SFM "FREE RUN" is assumed if no trigger mode is specified in the POLY mode. Trigger modes can be set in the POLY mode only by prefixing the waveform expression with one of the trigger statements shown above. You cannot set them in the OP2020 configuration as was done in the SFM. When a trigger condition has been properly specified the "MODIFIED" mode will report that trigger condition (in SFM terminology), and the trigger condition (mode) can be changed in the MODIFIED menu, as was the case in the SFM.

For example: FOR TRIG FOR 1m SIN(1K*T)
Will produce a 1 kHz sine wave, at 1 Vp amplitude as long as the trigger input is active high (gated).

POLY MODE (ARBITRARY) WAVEFORM EXAMPLES:

The best way to become familiar with the power and flexibility of the "2020" when using the "POLY" mode is to try some examples. In doing this, you will find that the syntax is intuitive and the machine is essentially self-teaching.

Single "FOR" statement examples (Figures 4 thru 13):

Figure 4 shows an AM modulation example in which a 5000 Hz sine wave is being modulated by a 500 Hz sine wave. Note that since both terms are expressed with unity amplitude coefficients, the modulation index is 100 % and the peak envelope amplitude is 2V. To vary the modulation index the low frequency term would be multiplied by a coefficient of other than one and you would have to include an outer parentheses pair around the multiplier and the sine term. Don't forget that implied multiplication is not done on the "2020", that is, you need the "X" operator which is displayed as an asterisk. Try changing the modulation index on this example.

Figure 5 is similar to the previous (Figure 4) example except that the times "X" operator was changed to an addition "+" operator so that the result is a summed 5000 Hz with 500 Hz, rather than a modulated, multiplied, composite.

Figures 6, 7, and 8, show FM modulation expressions using linear, logarithmic, and exponential sweep functions, respectively.

Figure 9 is a linear sweep similar to that shown in Figure 6 except that a square wave carrier is used in this case.

Figure 10 shows a linear function of time (1500 X t) multiplied by an exponential function or time (e raised to the minus 3000 X t).

Figure 11 shows a 1.5 kHz carrier modulated by an exponentially increasing ramp function.

In Figure 12, we asked for a 500 Hz sine wave for one half cycle (1 ms) and since the trigger mode is FREE RUN, the function repeats continuously to produce a Full Wave Rectified pattern, as shown.

Figure 13 shows a (SIN X)/X pattern. Note that the indeterminate value that results at 0/0 is avoided by adding one to the numerator and denominator and that the peak of the function was offset from zero time by the (t-a) notation.

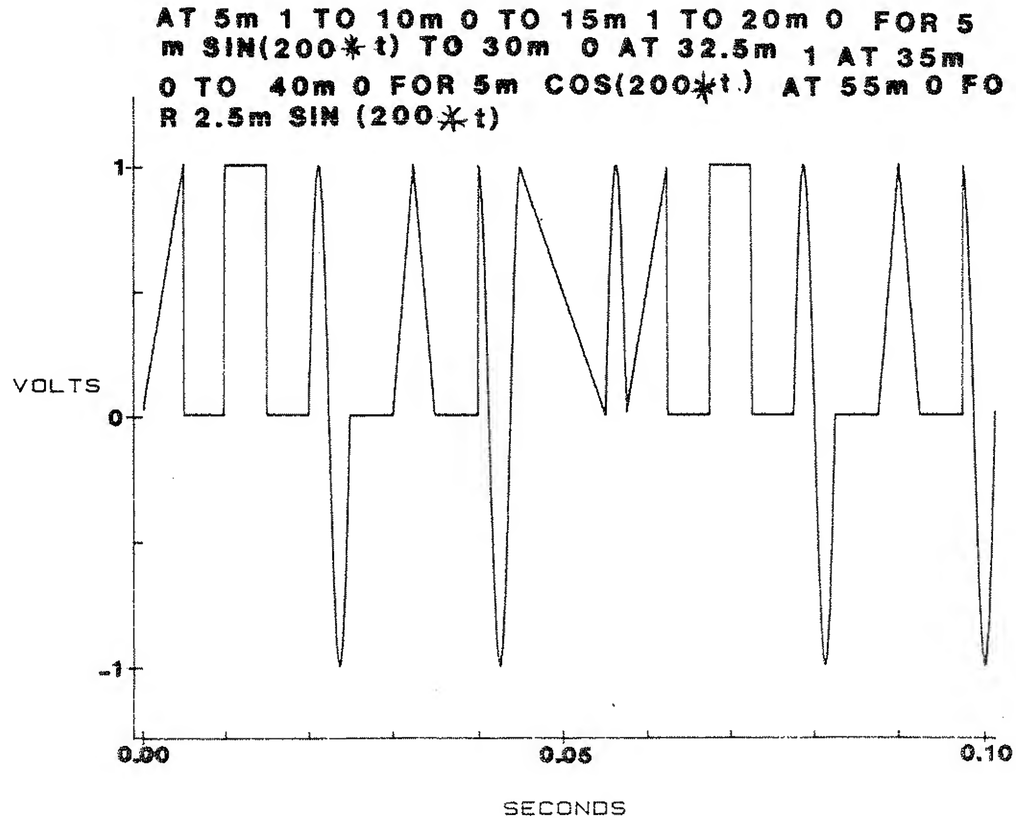


FIGURE 3

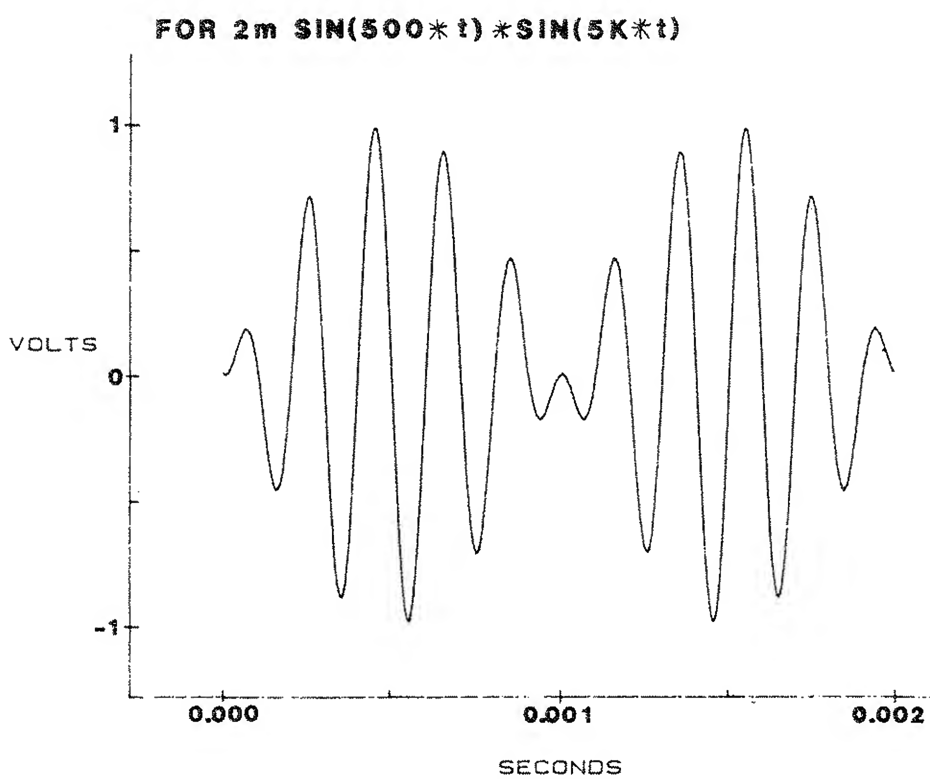


FIGURE 4

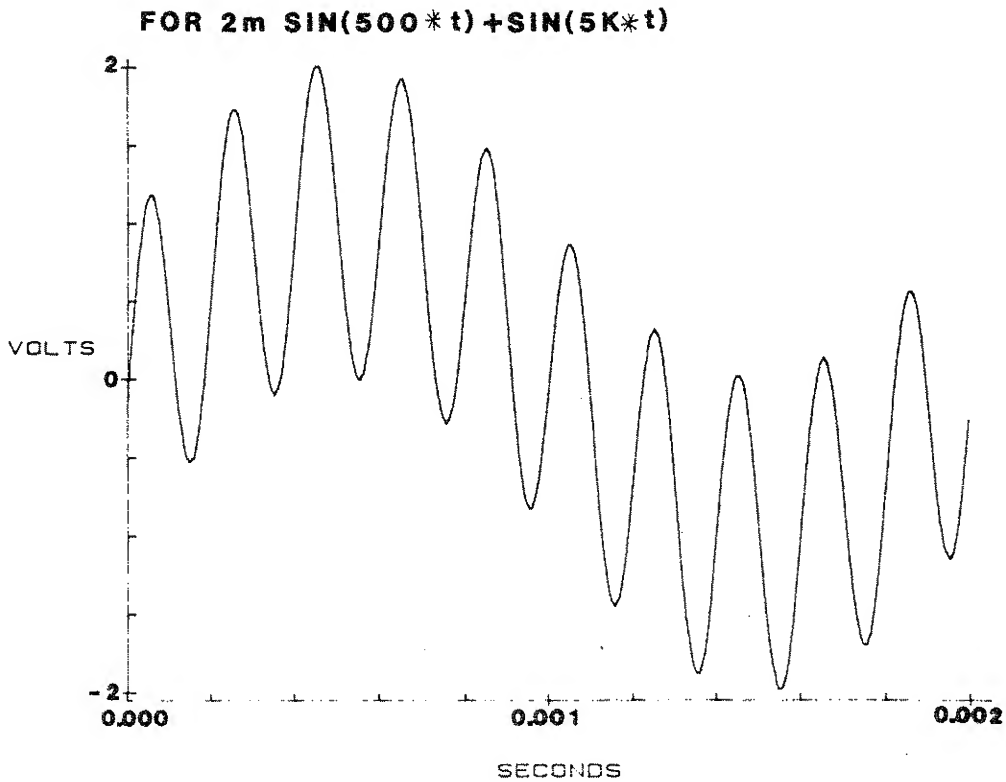


FIGURE 5

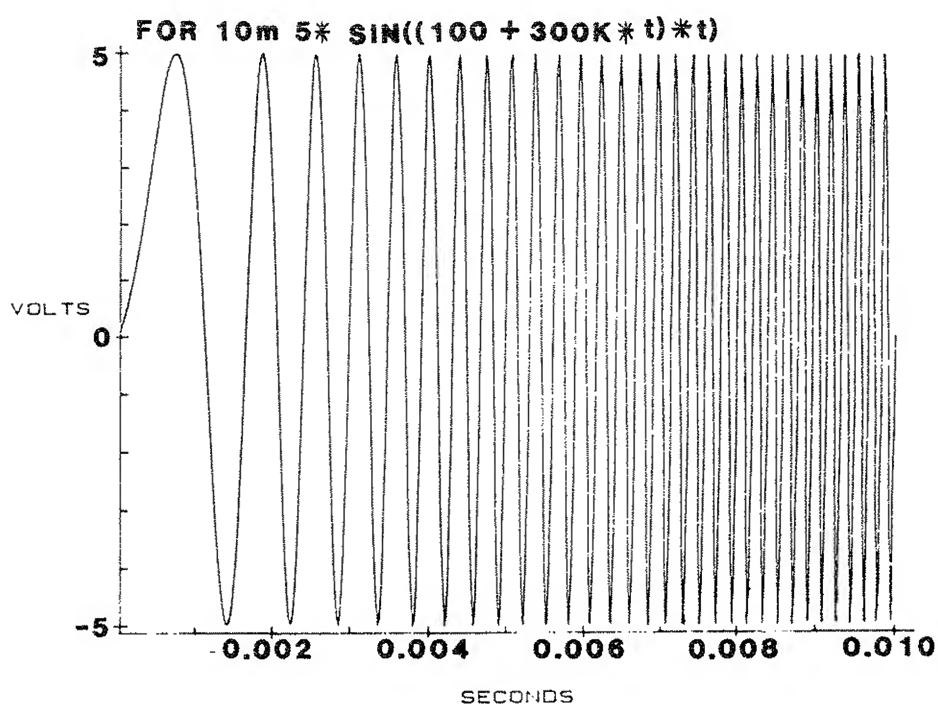


FIGURE 6

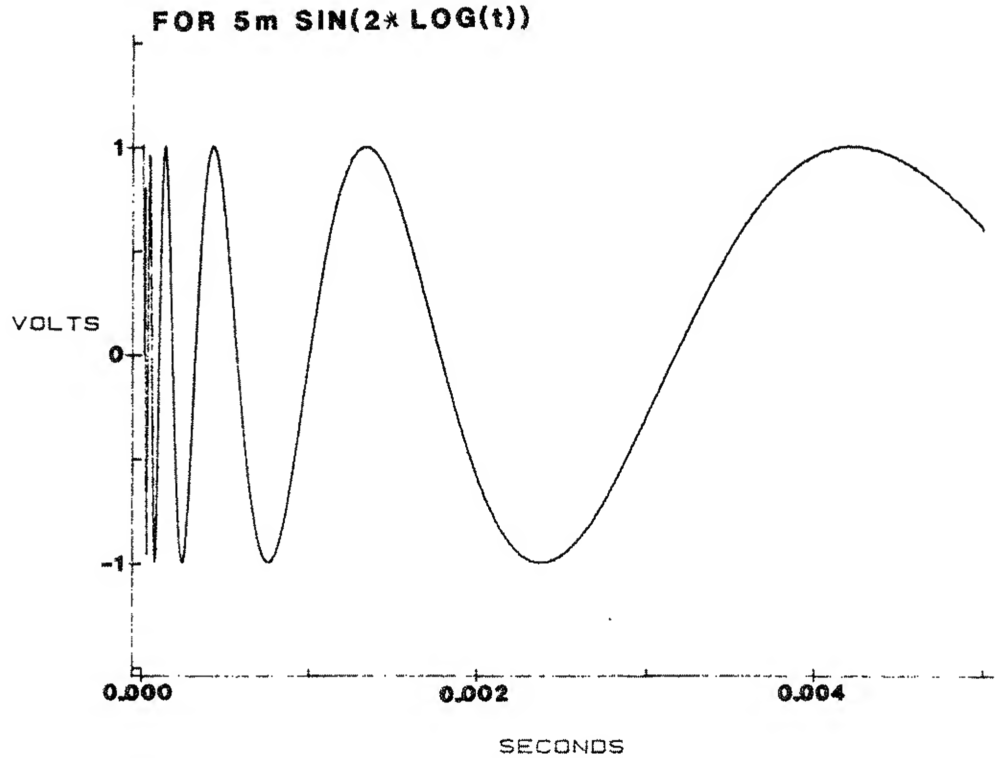


FIGURE 7

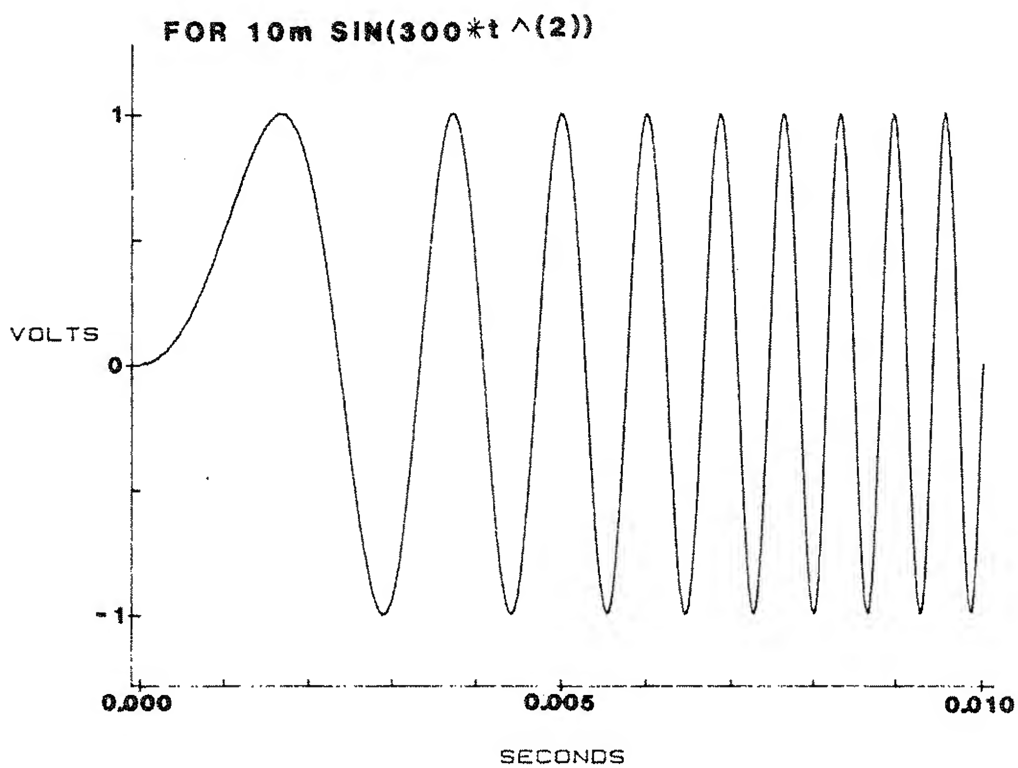


FIGURE 8

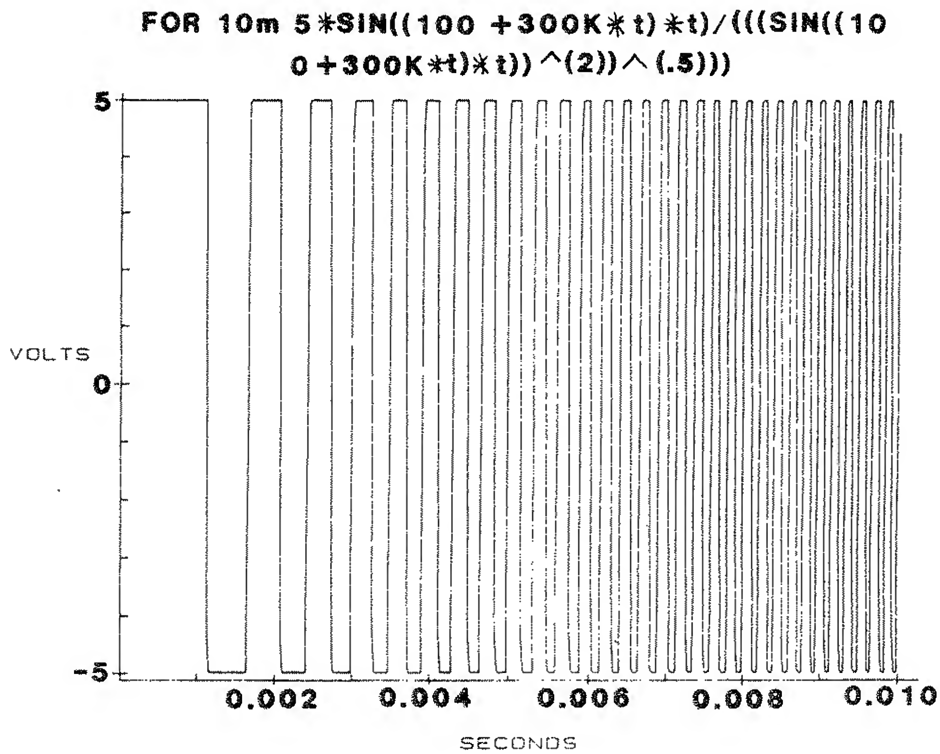


FIGURE 9

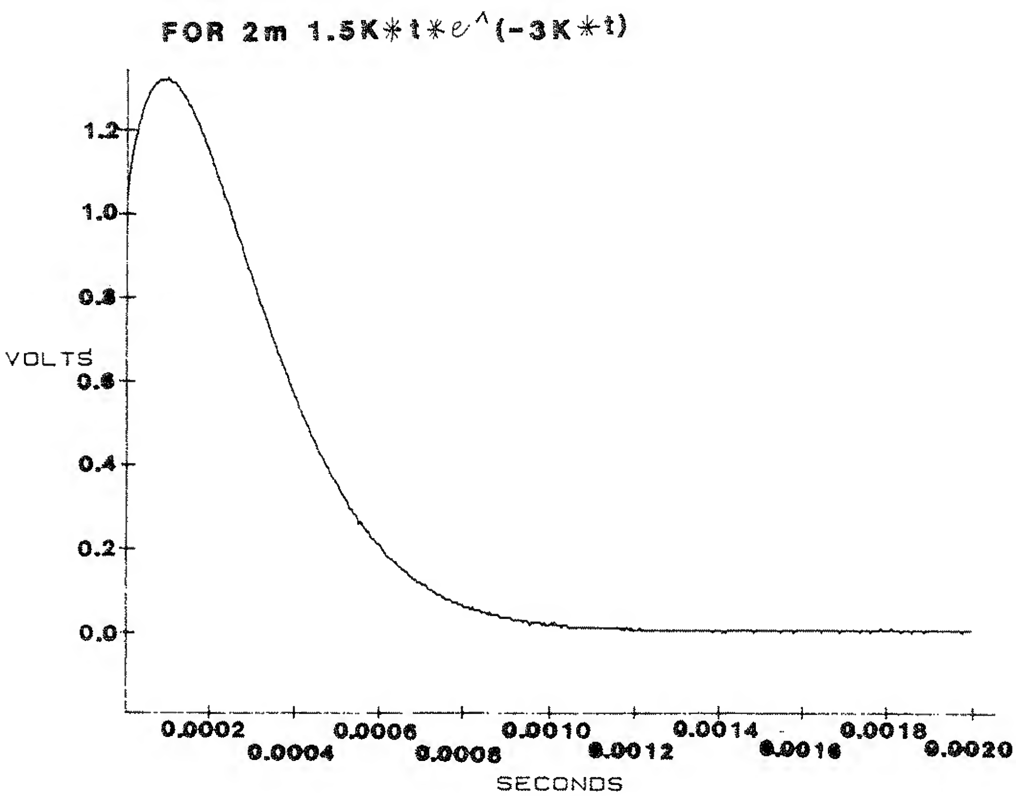


FIGURE 10

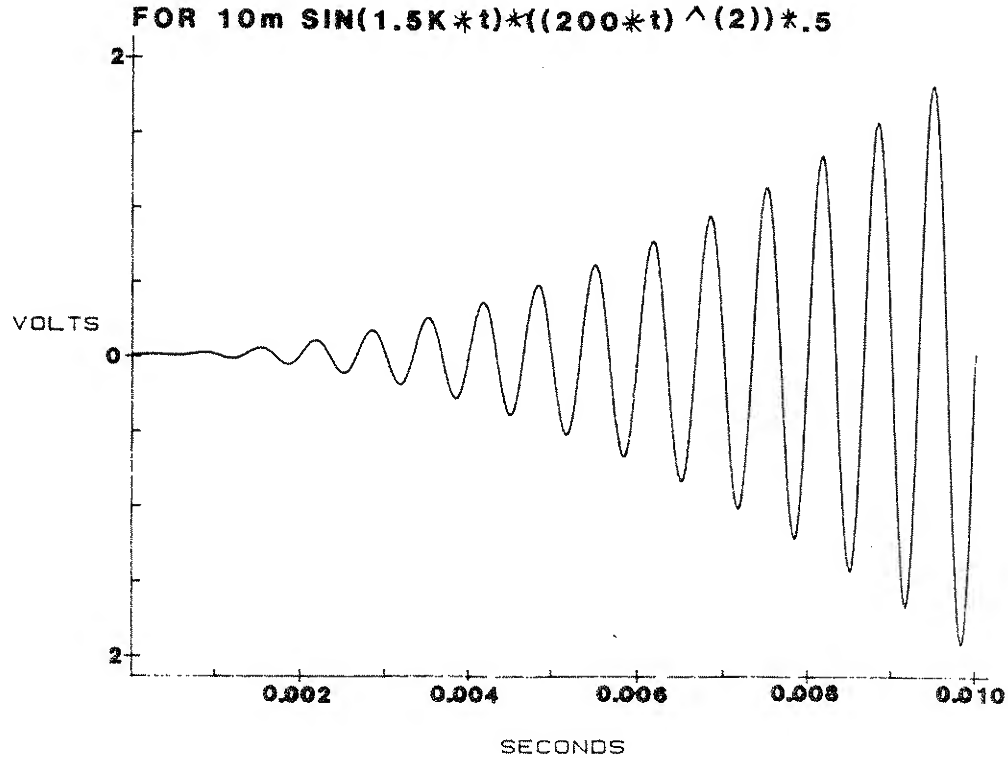


FIGURE 11

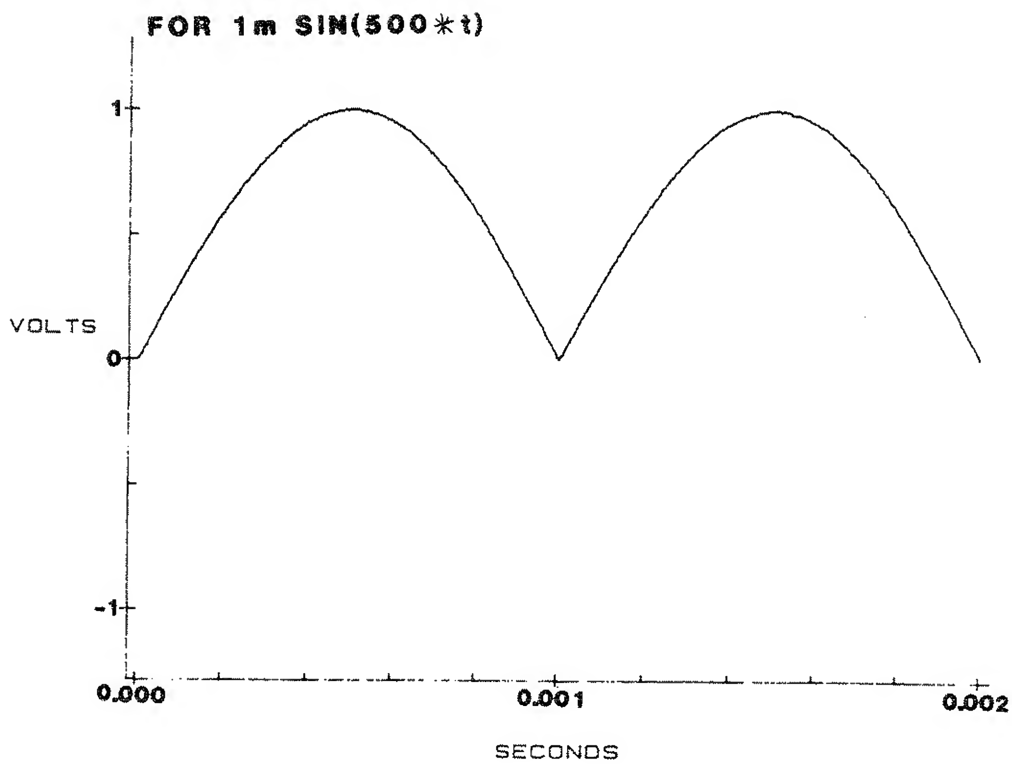


FIGURE 12

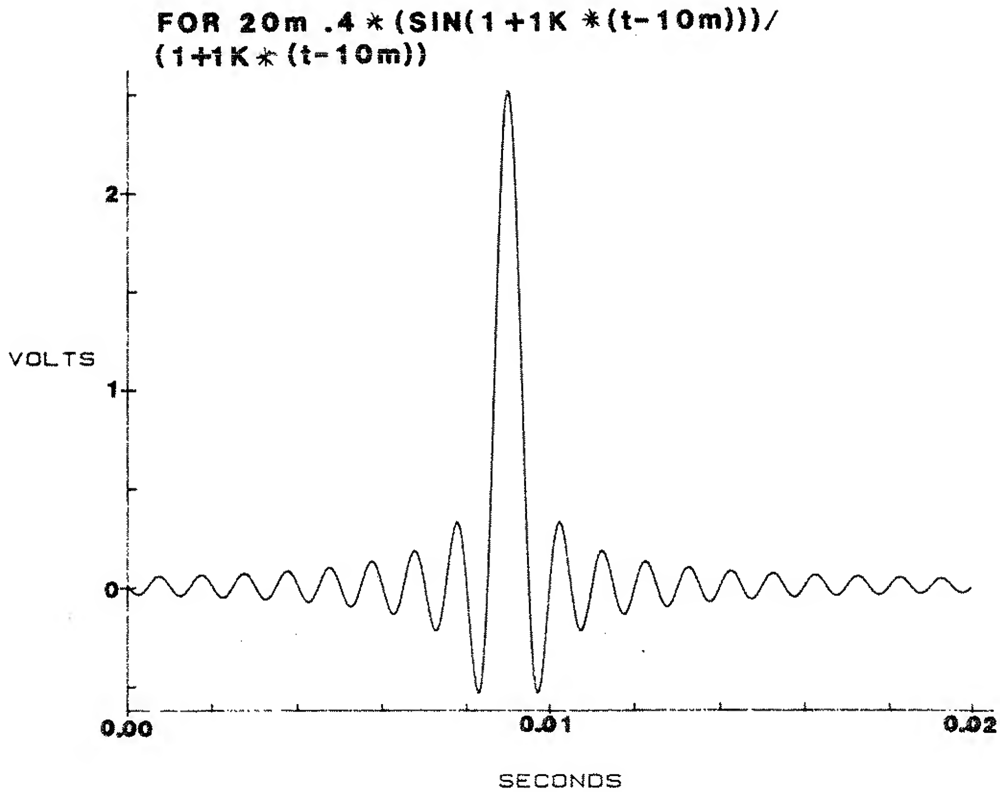


FIGURE 13

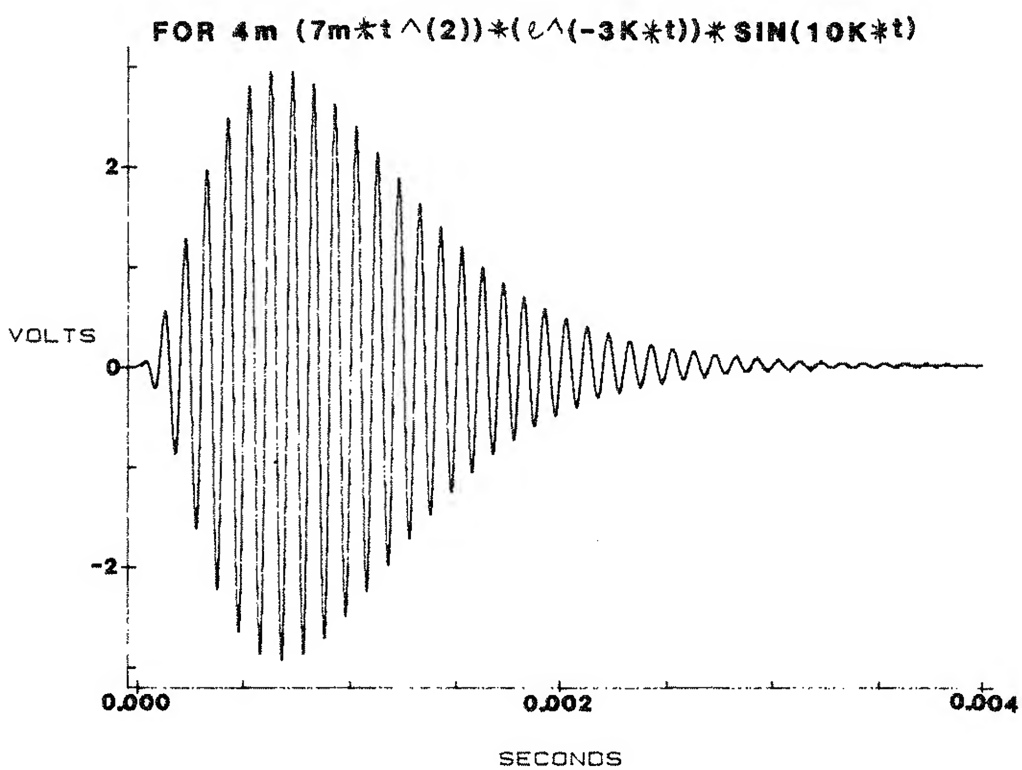


FIGURE 14

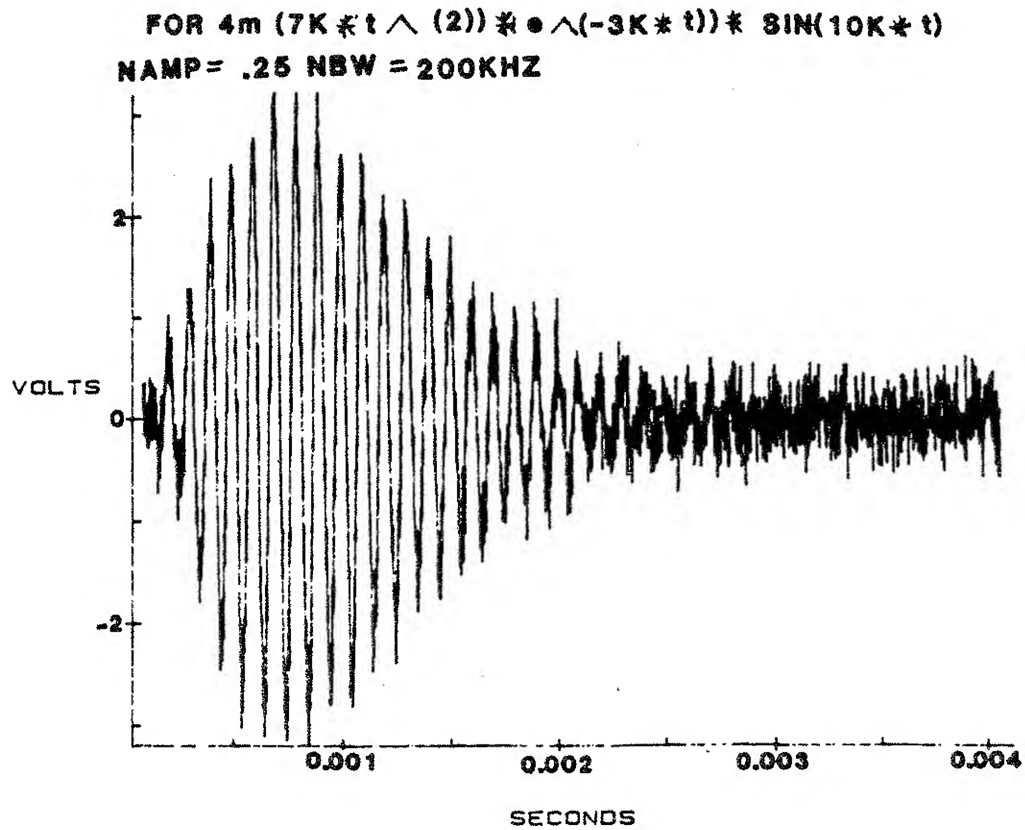


FIGURE 15

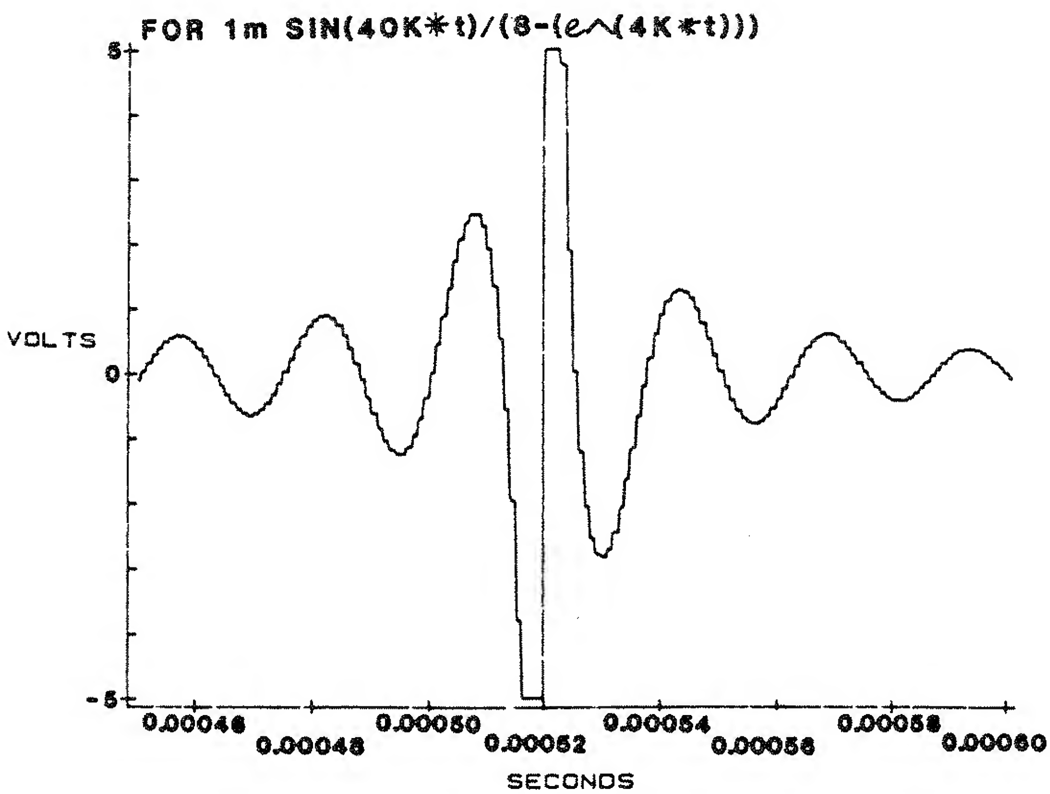


FIGURE 16

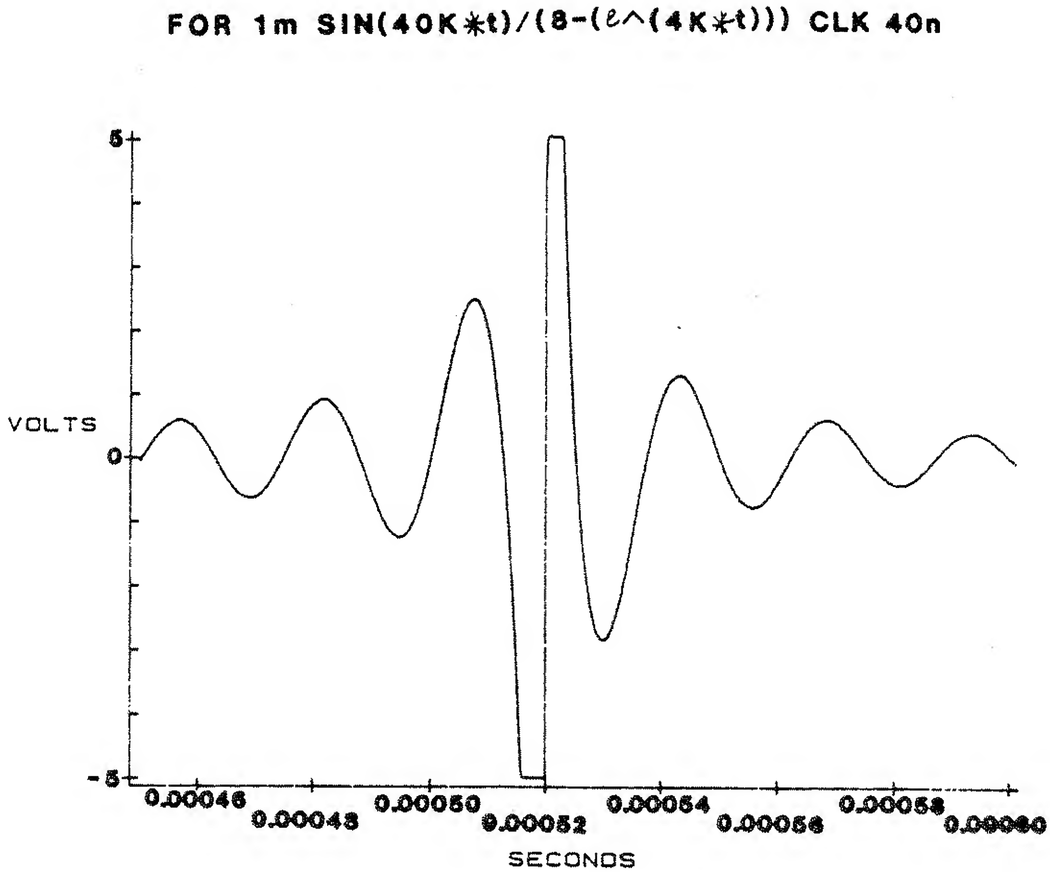

FOR 1m SIN(40K*t)/(8-(e^(4K*t))) CLK 40n
VOLTS
5
0
-5
0.00046
0.00048
0.00050
0.00052
0.00054
0.00056
0.00058
0.00060
SECONDS

FIGURE 17

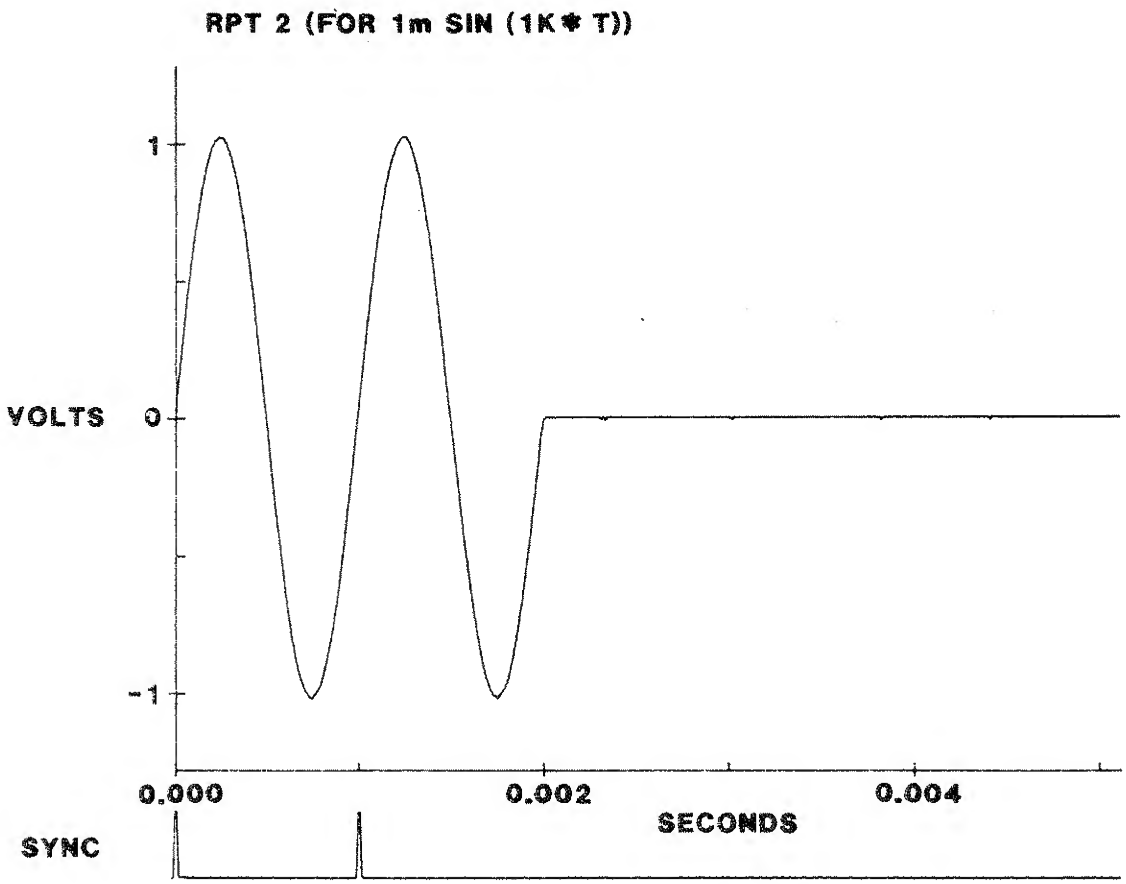
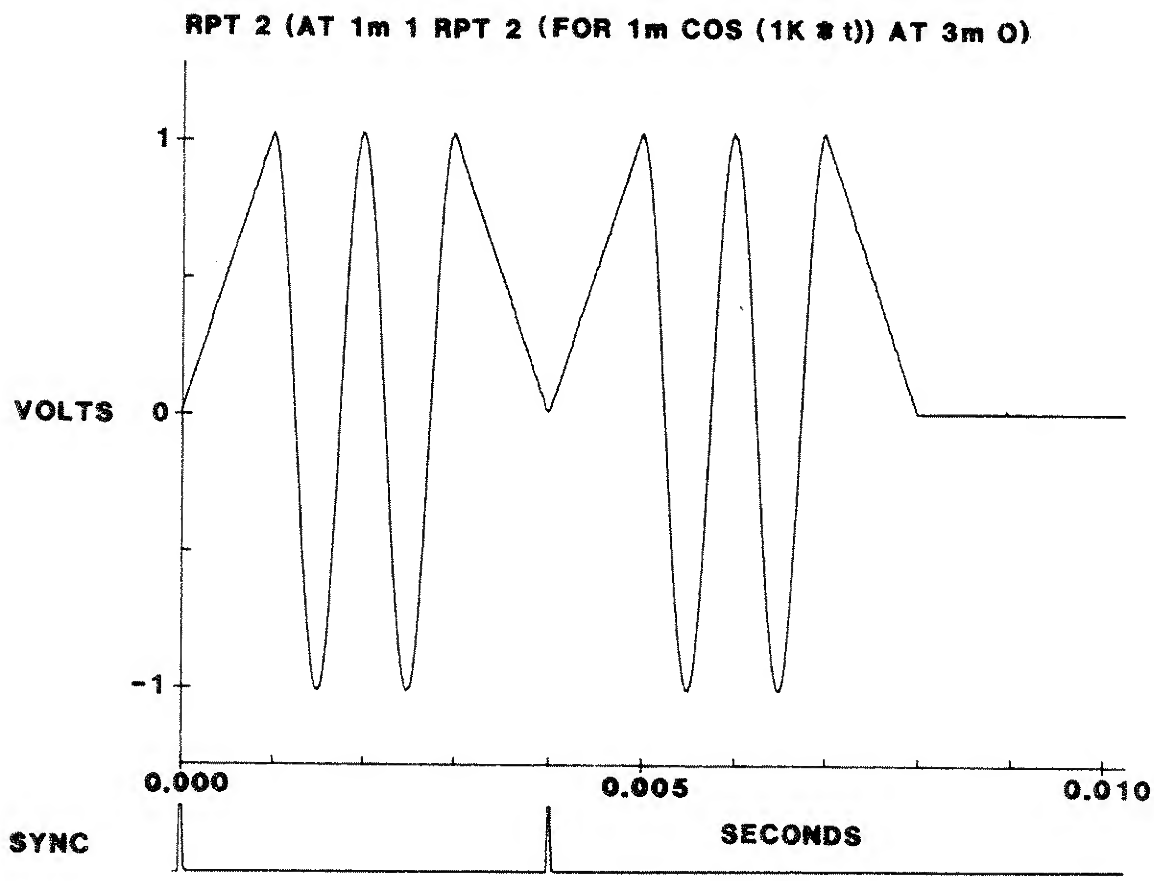


FIGURE 18



RPT 2 (AT 1m 1 RPT 2 (FOR 1m COS (1K * t)) AT 3m 0)
1
VOLTS 0
-1
0.000
0.005
0.010
SYNC
SECONDS

FIGURE 19

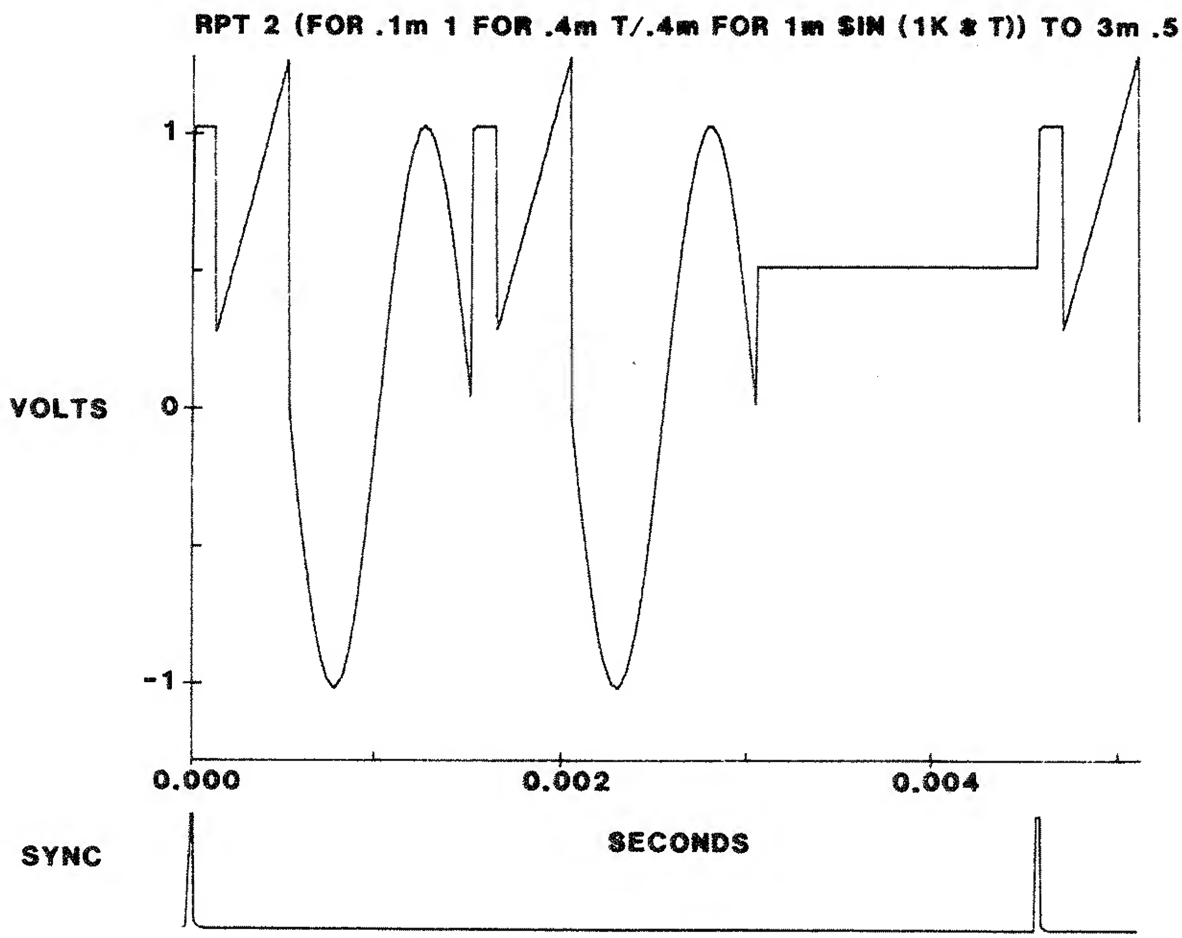
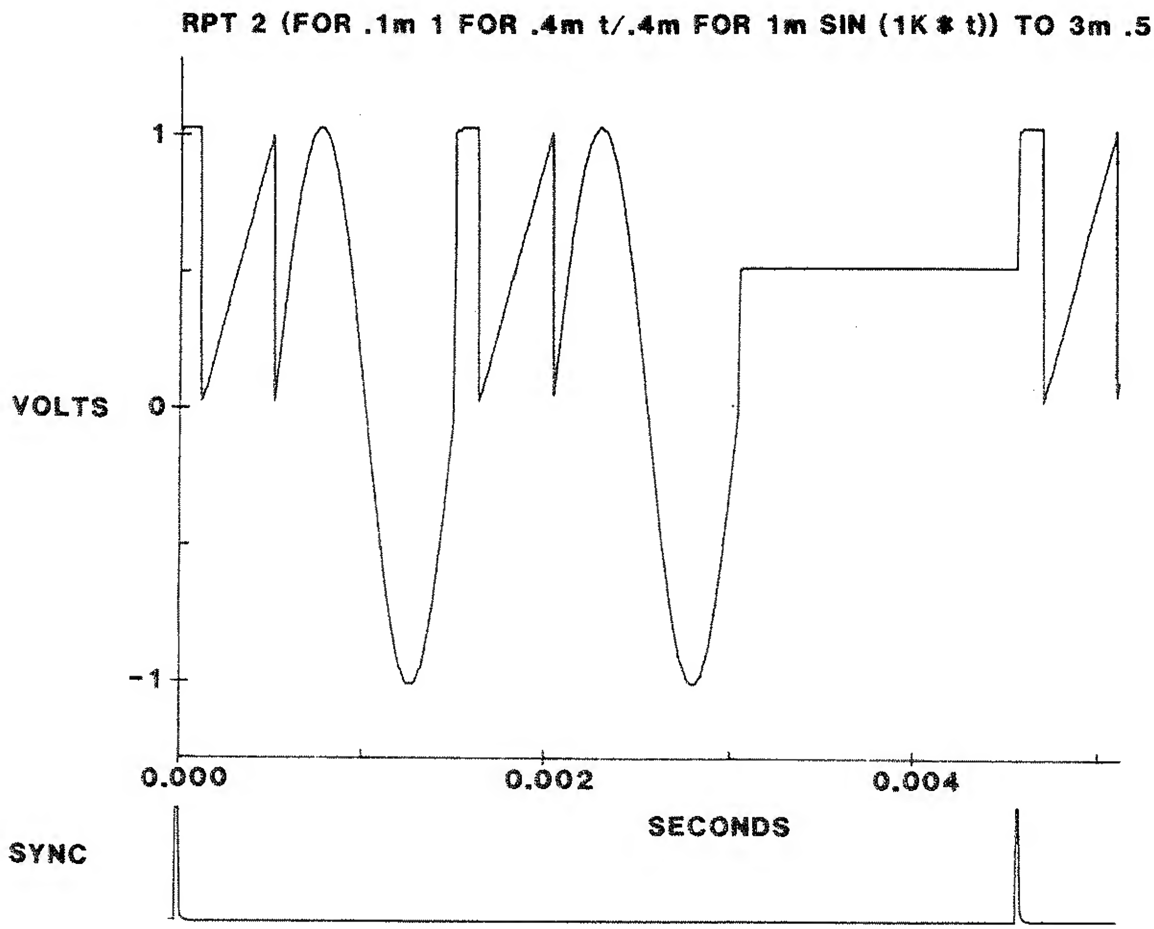

RPT 2 (FOR .1m 1 FOR .4m T/.4m FOR 1m SIN (1K * T)) TO 3m .5
VOLTS
1
0
-1
0.000
0.002
0.004
SECONDS
SYNC

FIGURE 20



RPT 2 (FOR .1m 1 FOR .4m t/.4m FOR 1m SIN (1K * t)) TO 3m .5
VOLTS
1
0
-1
0.000
0.002
0.004
SECONDS
SYNC

FIGURE 21

MODIFIERS (S/N, OFST, MARK, CLK, FILT):
Modifiers are quite different from the previously described DIRECTIVES. Whereas a "directive" as FOR, TO, AT, etc. is an integral part of the waveform expression; a "modifier" as S/N, OFSET, etc. is appended to the end of a waveform expression as a special instruction which can be changed at RUN TIME by invoking the "MODIFIED" mode.

S/N (Signal plus Noise):
When the flashing CURSOR is one or more locations past the last character in a waveform expression, depressing the "S/N" key will cause two value fields to appear. Namely, [NAMP =] and [NBW =] which stands for Noise Amplitude and Noise Bandwidth, respectively. The operator is then expected to enter the noise parameters (Amplitude and Bandwidth) to produce the desired "signal plus noise" condition. For the allowable values relative to these noise parameters refer to the Noise Field description in the Standard Function Mode Section of this manual. To obtain a specific Signal-to-Noise ratio, the operator must specify a particular noise amplitude (in rms volts) and noise bandwidth based on the operators' knowledge of the rms signal value and signal bandwidth that is represented by the waveform expression. Figures 14 and 15 illustrate the use of the NOISE MODIFIER. In Figure 14, we have synthesized a pulse modulated r.f. carrier signal that resembles a LORAN-C navigation signature. Since an actual receiver output would generally be corrupted by noise, this real life situation has been emulated in Figure 15 by specifying a noise MODIFIER in the form of NAMP = .25 (units are understood to be in volts) and NBW = 200 kHz. Note that the NBW must be one of the realizable bandwidth choices from the following selection list: 2 MHz, 200 kHz, 20 kHz.

OFST (Offset):
A dc offset term can be specified independently of any offset that may be implied by the mathematical waveform expression. If the evaluated waveform expression contains a dc term, the externally specified dc term (by means of OFST) is simply added to the mathematically implied offset. The peak signal plus offset cannot exceed the output full scale range of +5V to −5V into 50Ω (±10V open circuit). This offset value is specifed at the end of the waveform expression by keying OFST followed by the value in volts with an optional equals sign. For example: OFST = .3 or OFST .3 or OFST 300m would all result in a positive 0.3V offset; whereas OFST −.3 would yield a negative 300 mV offset. A complete typical equation might look like this:
FOR 1m PI *SIN(1K * T) OFST .3

This example would produce a 1 kHz sine wave with a peak amplitude of 3.14159V (PI) with a +0.3 Vdc offset. Note that the evaluation period, 1 ms, is one period at 1 kHz.

MARK (Marker Output):
A rear panel "Marker" output is provided to produce a positive logic level transition at a time ¾marker time¼ after the leading edge of the "Sync Pulse" (also a rear panel signal). Like all other MODIFIERS this is specified at the end of the waveform description. For example:

FOR 1 m PI*SIN(1K*T) OFST .3 MARK 156μ

This is the previous example with a MARKER specified at 156 μs. As in the case of all MODIFIERS, an equal sign is optional. That is, we could have specified MARK = 156μ.

FILT (Filter):
One of ten internally available Low Pass Filters can be applied to the Analog Output Function by specifying [FILT =] followed by the filter cut-off frequency which must be one of the available choices; which are, 20 kHz, 50 kHz, 100 kHz, 200 kHz, 500 kHz, 1 MHz, 2 MHz, 5 MHz, 10 MHz, and 20 MHz. Then to apply a 20 kHz filter to the waveform of the previous example we would have:

FOR 1m PI*SIN(1K*T) OFST .3 MARK 156μ FILT = 20K

Again, the equal sign is optional.

CLK (Clock):
This refers to the waveform evaluation interval used by the 2020 to construct the Output Function. If a clock rate is not specified by the operator, the "2020" will choose one that is consistent with the waveform time duration and the Output Memory that is specified in the OP 2020 set-up configuration (refer to the OP CODE Section of this manual). If a particular Clock Rate is forced by the CLK modifier that requires more output memory than that which was partitioned in the OP 2020 configuration, the specified clock rate will dominate and the number of solution points will automatically be extended as required to achieve the waveform duration time at the specified evaluation (clock) interval; provided of course that sufficient memory is installed and the clock rate is achievable. Appropriate ERROR messages will warn the operator if either of the foregoing limitations are encountered as the result of a requested clock rate. The clock modifier (CLK) is appended at the end of a waveform description as in the previous examples. Figure 16 shows a waveform that was evaluated at the default clock rate of 1 μs that resulted from a MAX MEM set-up configuration of 1000 points (ref OP 2020) and a FOR statement of 1 ms. Note that the plots of Figures 16 and 17 show only the center portion (0.45 to 0.6 ms) of the described 1 ms waveform. In Figure 18, the discrete data steps (1 μs each) are apparent. If it is desired that the output waveform be formed with better horizontal resolution, the operator can force a particular clock rate as a "modifier" at the end of the waveform expression as shown in Figure 17. In this case (Figure 17), we specified CLK = 40n to yield a solution each 40 ns instead of the original 1000 ns (1 μs). Observe that the OP 2020 configuration set-up is still specified as MAX MEM = 1000. However, forcing the particular clock rate of 40 ns now requires a 25000 point solution since the FOR statement (in the waveform description) still requires a 1 ms execution time. Since something must give, the MAX MEM 1000 point statement is automatically overridden. It should be noted here that the same 40 ns clock resolution could have been achieved without the CLK MODIFIER by restating the MAX MEM set-up configuration as 25000 points in which case the default clock would have been 40 ns (1 ms/25000 = 40 ns). With reference to Figure 16; if we had tried to increase the clock rate (decrease clock period) by going to the "MODIFY" mode and changing the CLK = 1 μs to CLK = 40 ns the horizontal resolution would not have changed. What would have changed is the waveform execution time which would have gone from 1 ms to 40 ns since the clock statement in the modified mode refers to the output clock and not the evaluation clock. The evaluation clock determines horizontal resolution while the output clock determines output frequency.

The maximum clock frequency is 25 MHz (40 ns) in the 25 MHz version and 100 MHz (10 ns) in the 100 MHz version. In either version the minimum Clock Rate is 687.173s.

IMPORTANT: all modifiers must be separated from the body of the POLY expression by at least one space, and modifiers can be strung with space separators, for example:
{POLY expression} [space]CLK=1μ[space]FILT=20K etc.

GENERATING SWEPT WAVEFORMS:
The "2020" can synthesize waveforms using its single independent variable time. The general form of sine functions generated on the "2020" is JV = SIN (PHI (T)) where PHI(t) represents the phase of the sine wave and has units of cycles or radians depending on the calculation mode selected (CYC/RAD). If PHI(t) = f*t, then f has units of cycles/s (hertz) or radians/s. The instantaneous frequency of this function can be calculated by evaluating the derivative of PHI(t) at time t.

FREQ(T) = d PHI(t) / dt

Linear Sweep Example:

To generate a linear frequency sweep with base frequency B and a sweep rate of MHz/s:

```
FREQ(T) = B + (M*T)        {SLOPE INTERCEPT FORM}
 PHI(T) = INT (FREQ(T) DT)
        = INT (B + M*T)
        = B*T + (M/2) * (t  (2)) + c      {where c = phase constant}
```

Note: INT refers to the Integral for which there is a function key on the "2020".

A 5 ms sweep from 1 kHz with a sweep rate of 2 kHz/1 ms can be described on the "2020" as :

```
    FOR 5m SIN(INT(1k+2k/1M*T)) CLK=1μ
OR: FOR 5m SIN(1k*t+2k/1m/2*(t  (2)) CLK=1μ
```

Note that we cannot simply write a frequency equation {FREQ(t) + 1k+2k/1m*t}, and plug it into the "2020" as:

```
FOR 5m SIN((1k+(2k/1m)*t)
```

because this would generate a sweep rate twice what is expected since the instantaneous frequency would be:

```
f(t) = d PHI/dt
     = d((1k+(2k/1m)*t)*t)/dt
     = 1k + 2*92k/1m)*t
```

Exponential Sweep Example:

To generate an exponentially swept sine wave with base frequency B and a sweep rate of 1 decade/ms gives FREQ(t) = B * (10 (t/m)). To produce 2 decades of an exponentially swept sine wave with a base frequency of 1 kHz and a sweep rate of 1 decade per 2.5 ms use:

```
FOR 5m SIN(INT(1k*(10  (t/2.5m)))) CLK = 10n
```

An interesting experiment would be to sweep out the filters on the "2020" using an exponentially swept sine wave such as:

```
FOR 20μ SIN(INT(100k*(10  (t/10μ)))) CLK=10n FILT=10k
  Note: for a 25 MHz system use CLK=25n
```

Will show the swept frequency response of the "2020" internal 10 kHz analog filter.

Note: The "2020" can only compute trigonometric functions with arguments up to 170k cycles (1m radian). Waveforms requiring more than 170k cycles may be split into 2 or more waveform segments.

MATH TOPICS:

Math range:

Math operations are performed over the numerical range of 1.7 EE−38 to 1.7 EE+38 with 24 bit resolution.

Trigonometric range:

The maximum argument for trigonometric functions is 170k cycles (1m radians).

Expression range:
A waveform expression, including modifiers and file name, can contain up to 520 displayable characters.

Parentheses nesting:
Parentheses nesting levels are unlimited.

Magnitude Notation:
[EE] key used for Engineering Powers of Ten Notation
Example [EE] [3] indicates times 1000
[2nd] [M] key sequence indicates Meg (X 1000000)
[2nd] [k] key sequence indicates kilo (X 1000)
[2nd] [m] key sequence indicates milli (X 1/1000)
[2nd] [μ] key sequence indicates micro (X 1/ 1000000)
[2nd] [n] key sequence indicates nano ((X 1/ 1000000000)

Special Constants:
[2nd] [e] key sequence indicates the constant 2.718 . . . . .
[2nd] [pi] key sequence indicates the constant 3.145 . . . . .

Math Functions:
[LOG] key indicates base 10 logarithm
[Ln] key indicates base e logarithm
[SIN] key denotes Sine function
[COS] key denotes Cosine function
[TAN] key denotes Tangent function
[INT] key denotes Definite Integral function when used in the format
[FOR] {x} [INT] {exp}
where {x} is a time duration over which integration is done
{exp} is the expression to be integrated

Exponentiation:
[y x] key is used to raise an expression {exp} to a power {x} and is used in the format {exp} [y(x)]. For example to raise 1000 times T to negative third power the key sequence would be: [1] [2nd] [k]
[X] [T] [Yx] [-] [3] [)]
note that the right parenthesis is used to close the left that was automatically given just after the "Y to x" key is depressed.

Polynomial Evaluation Order:
It is very important that the operator understand the order in which his various equation terms will be evaluated by the 2020. This evaluation order is:

First: All Parentheses pairs from innermost to outermost.
Second: Functions; for example, SIN, LOG, etc. NOTE that (y to the x) is NOT a function. If there is more than one function they are evaluated, in order, from Left to Right
Third: Multiplication, Division, and Exponentials (y to the x). In the case of multiple operations the order is Left to Right.
Fourth: Addition and Subtraction with the order again being Left to Right.

IMPORTANT: Since Exponentials are not given a higher priority than Multiplication and Division you may get solutions that you would not have normally expected with reference to the generally accepted algebraic evaluation ranking. To overcome this difficulty, it is good practice to include an outer parentheses pair around the expression which is to be raised to a power and another pair around the expression that represents the power. This insures that the y raised to x operation is given a higher priority than multiplication and division.

Negative Time:
Another idiosyncrasy of "2020" math that may lead you astray is the fact that negative T cannot be used. This can be overcome by notation fix in which you multiply T by minus one. That is instead of –T use –1*T and instead of –t use –1*t. Of course, the numeric value could be other than one; for example, –500*T etc.

Data Block Length Restrictions:
In any mode (SFN, POLY, or data Download). The 100 MHz version requires that the total number of data points be an integer multiple of 16. This is handled automatically in SFN. However in POLY or DOWNLOAD the "2020" will add the required number of points to your waveform to achieve the next highest multiple of 16. This self fill will appear as a dc portion appended to the end of your waveform. If you do not need clock rates faster than 40 ns this restriction can be bypassed by reverting to 25 MHz Version emulation as described in OP 2020 (MAX CLOCK).

REMOTE PROGRAMMING AND CONTROL:

Remote programming and control is accomplished with either the RS232 or GPIB (IEEE-488) communication options. Interface details are described in Section A and Section C of this manual.

Before utilizing the remote programming features of this instrument, we suggest that the user gain a thorough understanding of the material presented in Sections A, B, C, and D of this manual. This Section (E) is presented on the basis of that prerequisite.

Remote programming can be separated into two basic schemes. In the first, an external program controller is using the instrument to create waveforms in a manner that would correspond to that used by a manual operator; i.e., Standard Functions and Polynomial (arbitrary) mode. We will refer to this as "Remote Control." In the second case, the external controller (host) will be downloading direct data that will be used to generate waveforms and/or digital patterns that are determined by the external host. We will refer to this as "Remote Programming".

REMOTE CONTROL:

In this mode, Literal Mnemonics (except DATA), Valued Mnemonics, Constants and Key Numbers can be used.

LITERAL MNEMONICS:

Literal mnemonics operate without an assigned value and generally perform a command function or set a switch state. Table ET-1 is a list of such mnemonics that are recognized by the "2020". Observe the use of upper or lower case and note that some mnemonics have alternate names.

MNEMONIC	MEANING
RSET	Resets and re-initializes the machine
RESET	Resets and re-initializes the machine
CONFIG	Reads back listing of installed options
OP7	Enters installed options mode
RUN	Enables the current output
STOP	Disables the current output
REM	Locks out the front panel keys except for REM/LOC key
LOC	Returns control to local (front panel) state
RAD	Trigonometric arguments will be interpreted as radians/s
CYC	Trigonometric arguments will be interpreted as cycles/s
PURGE	Clears all waveforms from output memory
POLY	Puts the machine in the Polynomial (arbitrary) mode
CLR	Clears the edit buffer
−TRIG	Specifies trigger mode EXAMPLE: AT −TRIG
+TRIG	Specifies trigger mode EXAMPLE: TO +TRIG
TRIG	Specifies trigger mode EXAMPLE: FOR TRIG
e	Represents the number 2.7182818---- in a POLY expression
−e	Represents negative 2.7182818----
pi	Represents the constant 3.1415927-- in a POLY expression
PI	Represents the constant 3.1415927-- in a POLY expression
−pi	Represents the constant minus 3.1415927--
−PI	Represents the constant minus 3.1415927--
T	Represents the total time variable in a POLY expression Example: SIN(1k*T) Initial value = T
t	Represents the local time variable in a POLY expression Example SIN(1k*t) initial value = 0

INT	Evaluates Integral of an expression Example: FOR 100m INT(1k*T)
DIR	Reports listing of stored file names and available memory
DUMP	Reports listing of stored file names and their contents
INIT	Clears non-volatile RAM memory space
SSQR	Enters Standard Function SQUARE WAVE mode
SSIN	Enters Standard Function SINE WAVE mode
STRI	Enters Standard Function TRIANGLE WAVE mode
SNOI	Enters Standard Function NOISE mode
MOD	Enters/Exits MODIFY mode or Exits OP mode
RES	Enters/Exits MODIFY mode or Exits OP mode
RESTORE	Enters/Exits MODIFY mode or Exits OP mode
OP2020	Enters the OP2020 configuration set-up mode
OP488	Enters the OP488 GPIB (IEEE-488) configuration mode
OP232	Enters the OP232 RS232 configuration mode
ERROR	Reports next ERROR in error queue
DATA	Precedes a remote direct data download
ECHO=0	Disables update of "2020" screen display (default state)
ECHO=1	Enables update of "2020" screen display
NOISE=0	Enables Noise output, sets NOISE=ON; Default state is NOISE =ON with Noise Amplitude (NAMP) = 0.0V
NOISE=1	Disables Noise output, sets NOISE=HOLD
MAXMEM	Used to set maximum number of waveform data points in a POLY or SFM computation, actual will be less if waveform contains constant (dc) strings. Refer to OP Manual Section (sec. C) for minimum and maximum range of this mnemonic
TRIGLEV=0	Sets trigger Level to 0V
TRIGLEV=1	Sets trigger Level to 1V (default state)
CLKSRC=0	Sets CLOCK SOURCE to internal (default state)
CLKSRC=1	Sets CLOCK SOURCE to external
CLKLEV=0	Sets external Clock Level to 0V
CLKLEV=1	Sets external Clock Level to 1V (default state)
IDLEVOLT=0	Sets output idle voltage to 0V (default state)
IDLEVOLT=1	Sets output idle condition to OPEN
DIGOUT=0	Disables Digital Data Output (default state)
DIGOUT=1	Enables Digital Data Output
MODE=0	Sets "2020" to NORMAL mode of operation (default state)
MODE=1	Sets "2020" to MASTER mode of operation
MODE=2	Sets "2020" to SLAVE mode of operation
MAXCLK=0	Uses 40 ns as fastest clock to emulate 25 MHz version
MAXCLK=1	Uses 10 ns as fastest clock (default state on 100 MHz ver.)
EOIOUT=0	Disables EOI, End Or Identify
EOIOUT=1	Enables EOI, End or Identify (default state)
GET=0	Disables GET, Group Execute Trigger (default state)
GET=1	Enables GET, Group Execute Trigger
OUTSRQ=0	Disables SRQ, Service Request output (default state)
OUT SRQ=1	Enables SRQ, Service Request output
TALKSRQ=0	Disables SRQ, Service Request output (default state)
TALKSRQ=1	Enables SRQ, Service Request output

LISNSRQ=0	Disables Listen SRQ, receive Service Request
LISNSRQ=1	Enables Listen SRQ, receive Service Request
FASTIO=0	Disables High Speed DMA over GPIB Bus (default state)
FASTIO=1	Enables High Speed DMA over GPIB Bus
PROMPT=0	Disables Prompt character ( ) return to controller screen
PROMPT=1	Enables Prompt (default state)
ERRM=0	Sets error mode to "immediate" (default state)
ERRM=1	Sets error mode to "on request"

Table ET - 1

VALUED MNEMONICS:

The mnemonics listed in Table ET-2 establish a parameter value and are therefore followed by numeric value. The value range for these mnemonics are described in the appropriate section of this manual.

MNEMONIC	MEANING
AT	Interpolation DIRECTIVE Example: AT 1m 3 interpolates from 0 to 3V in 1 ms
FOR	Duration DIRECTIVE Example: FOR 5m (1k*T) produces 5 ms ramp of 1V/ms
TO	Specifies a waveform segment and time Example: TO 10m 3 means output 3V to 10 ms
RPT	Used to repeat wave segment and or provide n-shot capability. Example RPT 1 (FOR 1m SIN(1k*T) produces one cycle of a 1 kHz waveform.
SIN	Evaluates the sine of an expression Example: SIN(100k*T) or SIN(2*PI*100k*T)
COS	Evaluates the cosine of an expression Example: COS(1k*T) or COS(2*PI*1k*T)
TAN	Evaluates the tangent of an expression Example: FOR 1m TAN(1k*T)
EXP	Raises Y to the X-th power Example: For 1m SIN(1k*T)EXP(3) This example cubes the 1 kHz sinewave Note: EXP produces an UP ARROW on the 2020 display
LOG	Evaluates common (base 10) log of an expression Example: FOR 1m LOG(10k*T)
LN	Evaluates the natural (base e) log of an expression Example FOR 1m LN(10k*T)
CLK	Used to override system derived clock rate Example CLK = 40n
OFST	Specifies a total waveform dc offset Example: FOR 1m (1k*T) OFST 1 will offset the 1 kHz waveform by 1V Minimum: −5 Maximum: 5
NAMP	Specifies noise bandwidth in volts rms Example: NAMP 1.0
NBW	Specifies noise bandwidth in hertz Example: NBW 2M

FILT	Used to select one of 11 internal filters which includes NO filter. Example: FILT = 20M To select "NO" filter use FILT=50M
MARK	Used to select Marker Time in seconds Example: MARK = 3.5m
RCL	Recalls named directory from memory Example: RCL F324
DEL	Deletes named directory from memory Example: DEL 123
FREQ	Specifies Frequency in Standard Function Mode (SFM) Maximum is: FREQ=3.25M (for 25 MHz version) FREQ=6.5M (for 100 MHz version)
PER	Specifies waveform Period in SFM Minimum: PER=153.8n (for 100 MHz version) PER=307.7n (for 25 MHz version)
AMP	Specifies waveform amplitude in SFM Minimum: AMP=2.5m Maximum: AMP=5
HIGH	Specifies waveform maximum (can be ±) value in SFM
LOW	Specifies waveform minimum (can be ±) value in SFM Note: HIGH/LOW inherently sets AMP and OFST
TRIGMODE	Selects one of twelve (12) trigger modes as follows: TRIGMODE=0 FREE RUN TRIGMODE=1 +START TRIGMODE=2 −START TRIGMODE=3 +GATED TRIGMODE=4 −GATED TRIGMODE=5 +STOP TRIGMODE=6 −STOP TRIGMODE=7 +TO+ TRIGMODE=8 −TO− TRIGMODE=9 START TRIGMODE=10 STOP TRIGMODE=11 TOGGLE NOTE: 9, 10, and 11 are used only when "GET" response is used as the TRIGGER source in the OP488 configuration set-up
DLY	Specifies DELAY in SFM
SYM	Specifies SYMMETRY in SFM
DUTY	Specifies DUTY CYCLE in SFM
PLSW	Specifies PULSE WIDTH in SFM
BADR	Sets the BUS ADDRESS of the "2020" for GPIB Example BADR=n where $0 < n < 31$

Table ET - 2

KEY CODES:

In addition to the foregoing mnemonics (Tables 1 & 2), the remote program can simulate direct key presses by sending KEY=n where "n" corresponds to one of the 64 front panel keys in accordance with the following table (Table ET-3):

KEY NUM.	KEY NAME	KEY NUM.	KEY NAME
0	FILT	32	9
1	FIELD	33	8

2	FAST	34	6
3	(	35	EE
4	LEFT ARROW	36	5
5	F	37	2
6	2nd SHIFT	38	3
7	TO	39	0
8	RIGHT ARROW	40	OFST
9	DOWN ARROW	41	SN
10	SPACE	42	EXP
11	AT	43	ENTER
12	T	44	TAN
13	t	45	COS
14	LN	46	STO
15	SIN	47	NO
16	7	48	TRIANGLE
17	FORMAT	49	–
18	4	50	SINE WAVE
19	DECIMAL POINT	51	NOISE
20	1	52	X
21	UP ARROW	53	/
22	CLR	54	SQUARE WAVE
23	)	55	+
24	CLK	56	DEL
25	MARK	57	TRIGGER
26	LOG	58	RCL
27	DIR	59	YES
28	INT	60	REM/LOC
29	FOR	61	CYC/RAD
30	RPT	62	RESTORE
31	HELP	63	R/S

Table ET - 3

For further clarity, the Key Codes are shown in Figure EF - 1 with the key numbers superimposed on a "2020" key location drawing.

REMOTE CONTROL EXAMPLE:

The following example shows the use of remote control mnemonics to generate a pulse train at a 10 kHz rate with a 1 μs pulse width. The pulse amplitude is to be 3.25V with a 0.5V negative dc offset. And, we wish to corrupt the pulse with 0.25V rms of noise where the noise bandwidth is to be 20 kHz. In addition, we desire that the SYNC output occur 2 μs before the leading edge of the output pulse which corresponds to 98 μs from the previous pulse leading edge in the output pulse train.

MNEMONIC	COMMENT
STOP	Disables the Function Output
SSQR	Selects Standard Function SQUARE WAVE mode
FREQ = 10k B	Sets frequency to 10 kHz
AMP = 3.25	Sets pulse amplitude to 3.25V
PLSW = 1μ	Sets Pulse Width to 1 μs
OFST = −.5	Sets Offset to −0.5V
DLY = 2μ	Sets Delay to μs *Note: in this example we could also have used DLY = −98μ*

NBW = 20k	Changes Noise Bandwidth from its default value of 200 kHz
NOISE = 0	Activates Noise source
NAMP = .25	Sets Noise Amplitude to 0.25V rms
RUN	Executes the Output Function

Note that the trigger mode is FREE RUN. The ( ) sign, in the above program indicates "carriage return". The parameter value or control command is ENTERED automatically by the "carriage return" as opposed to the use of the ENTER key when the "2020" is being manually operated.

If while the above function is running we wish to change a parameter, the revised mnemonic would be sent for that parameter only. For instance, if we wish to change the pulse width to 3 μs the following mnemonic would be sent:

PLSW = 3μ

This example parameter change (Pulse Width) requires recomputation of the waveform which will take on the order of 200 ms. Parameter changes that involve hardware attributes only and do not require recomputation as Amplitude, Offset, Filter and Noise ON/HOLD will take place approximately 35 ms after receipt of the "carriage return".

REMOTE PROGRAMMING (DIRECT DATA DOWNLOAD):

The "2020" can generate analog and/or digital waveforms that are externally composed and downloaded via a remote host. Direct Data downloads are done from a host computer using RS232 or GPIB IEEE-488. The communication rate is in accordance with the selected BAUD rate if RS232 is used or approximately 2K Bytes/s over GPIB IEEE-488 unless the high speed DMA option is installed **and selected;** in which case, the transfer rate is approximately 300K Bytes/s.

DOWNLOAD FILE TYPES:

There are two types of files, named and unnamed.

1. Unnamed files are preceded by the ASCII string "DATA". Only one unnamed file can exist in output memory. Loading another file, computing a Standard Function, or POLY function will purge the unnamed file. The unnamed file will appear in the file directory as "DATA". The appended dot (.) indicates that this is a binary (output memory) file and it is therefore volatile. Do not send the dot (.) with the file name, it is automatically appended in the "2020".
2. Named files are preceded by the ASCII string "DATA FILENAME" where the filename will be an Alphanumeric string of less than 8 characters where the first character is Alpha and the last character. For example "MYFILE"; as in type 1 (above) this file name appears in the directory with the appended dot to indicate that it is a volatile output memory binary file. Up to 21 named data files can be resident in output memory at one time. If the extended non-volatile memory option is installed up to 32 files can be downloaded. Note: even though these DATA files are stored in volatile Output Memory, non-volatile RAM space is reserved for the non-data overhead required to support the file handler; thus the number of files that can be supported is dependent upon the amount of installed non-volatile RAM. Since the Output Memory contains the Data Points only, the total number of data points (sum of all downloaded files) is limited by the amount of Output Memory that is installed. The minimum amount of output memory is 65535 points in the 25 MHz version and 131071 points in the 100 MHz unit. Either unit can be optioned up to as much as 524287 points.

   The advantage to this format (which we refer to as segmented output memory) is that any one of these files can be recalled in the conventional manner {RCL FILENAME} and run without

having to take the bus time necessary to download the file, or the computation time necessary to calculate a POLY or SFM expression. The access time is approximately 35 ms from the carriage return that follows the RCL command to the time that the new recalled waveform appears at the Function Output.

DOWNLOAD FILE CONSTRUCTION:

A data download file consists of three main parts:

The file is **always preceded by** the ASCII string "DATA" or "DATA FILENAME" which indicates that a direct data file is to follow.

2 A MAIN HEADER always follows the opening ASCII string (DATA). The Main Header conveys hardware set-up parameters such as; clock rate, amplitude, offset, filter bandwidth, noise amplitude and bandwidth, etc. There can be only one Main Header except in the case of segmented (multiple) output memory files which will be discussed later.

3 A Data Set consisting of a DATA HEADER, waveform DATA, and CLOSING HEADER follows the Main Header.

4 The Data Set (item 3 above) can be repeated depending upon whether repeat and/or constant compression sections are contained in the waveform.

MAIN HEADER:

The main header contains the hardware settings appropriate to the waveform being downloaded. It is 32 bytes long and is coded in the following manner:

parameter	**num of bytes**	**starting byte**	**remarks**	**see note**
Clock Period	4	0	IEEE F.P. units in seconds	1,2
Offset	4	4	IEEE F.P. units in volts	1,2
Signal Amp.(p-p)	4	8	IEEE F.P. units in volts	1,2
Noise Amp. (rms)	4	12	IEEE F.P. units in volts	1,2
Noise Bandwidth	4	16	IEEE F.P. units in hertz	1,2
Filter Cut-off	4	20	IEEE F.P. units in hertz	1,2,3
Trigger mode	2	24	Unsigned 16 bit integer	2,4
Not Used	2	26	0, 0 (only)	5
Not Used	4	28	0, 0, 0, 0 (only)	5

You will note that only waveform parameters are passed in the Main Header. Any attribute that is not associated with the Function Output or Digital Output connectors is directly controlled with the appropriate mnemonic as given in Tables ET-1 and ET-2. For example; if you wish to envoke a Marker Output at 83.5 μs; send "MARK=83.5μ" at any convenient point in the program.

If you wish to change a Main Header parameter without having to re-send the entire program, send the mnemonic MOD to enter the "Modify" mode and then send the new parameter in accordance with the mnemonic listing given in Table ET - 2. To revert to the original parameter value, send RESTORE.

NOTES:

1. IEEE Floating Point format is a 4-byte number representation. For computer languages like "C" and "Pascal" there are simple subroutine calls to get the IEEE floating point number. For "BASIC" language, we have written a simple conversion routine which is given in this Section entitled IE3FP.BAS. Additionally, as a fast aide, we have listed some common conversions from base 10 to IEEE in Table ET - 4.

2. The IEEE byte values are sent as the ASCII number representing the value of the byte (0 thru 255). In the case of Hewlett Packard computers using BASIC, CHR$ is used to make the conversion to ASCII numbers. On an IBM compatible PC using BASIC, use STR$.

3. There are ten internal L.P. filters arranged in a 1,2,5 sequence from 20 kHz to 20 MHz in addition to "NONE" which yields the full output response bandwidth. The "2020" will automatically choose the filter that is closest to the number that you specify in this field. If you want NO filter, specify 50 MHz or greater.

4. The numerical specification for Trigger Mode is as follows:

0 FREE RUN
1 +START
2 −START
3 +GATED
4 −GATED
5 +STOP
6 −STOP
7 +TO+
8 −TO−

5. The last block of 6 unused bytes is required in the download sequence and is to be filled with zeros. This space is reserved for future expansion capabilities.

DATA HEADER:

This header follows the main header and it tells the "2020" what type of data is to follow and how it is to be executed. With this header, the user has access to very powerful memory compression routines that either allow "n" times single or nested level repeats of particular data blocks as well as automatic looping on a constant value. These techniques allow substantial virtual expansion of the available output data memory.

This header is 10 bytes long and is presented in the following format:

Parameter	num. of bytes	starting byte	see note
Segment Type	2	0	note 1
Segment Length	4	2	note 2
Constant Value	4	6	note 2 (0, 2), note 4

NOTES:

1. The choices for Segment Type with their two byte descriptors are as follows:
   0, 1 Block type - used when there is a single set of data to be output
   with no repeated segments.

0, 2 Constant - used when a constant value is to be output for a period of time and the programmer does not want to simply fill successive memory locations with the same value.
0, 3 END - denotes that this is a closing data header and determines the end of a download sequence.
0, 4 Reserved - do not use.
0, 5 Repeat - denotes that the data set is to be repeated "n" times where "n" is determined by the "segment length" parameter.
0, 6 Repeat End - denotes the end of a repeated segment, see note 3 below on the use of loop counters.

2. The use of the Segment Length field will vary depending upon the seqment type (see note 1.) as described below:

If Segment

Type =	**The Segment Length is:**
0, 1	Unsigned 32 bit integer representing the length of the data block in two 16 bit words
0, 2	A 32 bit unsigned integer representing the number of clock pulses that determine the duration of the constant (dc) portion. Note that, the dc value is sent in the constant field (bytes 7 & 8).
0, 3	Fill with 0, 0
0, 5	The first two bytes are the Loop Counter to be used (see Note 3 below) which are either 0,0 or 0,1. The last two bytes are the length of the repeat seqment expressed as a 16 bit integer value.
0, 6	The first two bytes are the Loop Counter to be used (see Note 3 below). The last two bytes are unused and must be filled with 0, 0.

3. Loop counters keep track of the number of times that a waveform or waveform segment is to be repeated (looped upon). There are two loop counters 0, 0 and 0, 1. They can both count up to 65535 but are used differently. The programs RPTTEST0.BAS and RPTTEST1.BAS included in this Section illustrate their use. In RPTTEST1.BAS, loop counter 0,0 is used because this is an "n" shot repeat. That is, the entire waveform is repeated N times. The other counter (0, 1) is associated with multiple repeats and may be included inside (nested in) the 0, 0 counter but; 0, 0 may not be included in 0, 1. Be aware that the nested loop counter cannot be allowed to end on the same clock cycle as the outer loop counter when a clock period faster than 15 ns is being used. For clarity, we can relate these two loop counters to their use in the POLY expression mode of "2020" operation with which you are familiar. In the POLY expression: RPT 2 (RPT 5 (FOR 10 m SIN(1K*T) FOR 1m 0)

In this example, which parenthetically is not a downloaded data example, the RPT 2 is handled by loop counter 0, 0 and the RPT 5 is serviced by loop counter 0, 1.

4. The constant value is only used when Segment Type = 0, 2. Otherwise 0, 0, 0, 0 must be sent.

DATA:

This is the actual waveform data point information which is sent as ASCII code corresponding to the 16-bit integer value for the particular data point. This data is sent in a HIGH BYTE, LOW BYTE sequence. Note that the digital data output of the "2020" uses all 16 bits, whereas, the analog output uses the top 12 bits of the 16-bit word that is sent for the data point value. When using only the analog output waveform, the lower four bits can be taken for the Digital Output to be used as free form markers in addition to the system marker output; or they can form an independent four-bit word that exhibits a particular real-time relationship to the analog waveform output.

DATA is interpreted for the Analog Output as offset binary. Therefore, the HEX value of the downloaded data corresponds to the Analog output level as follows:

FFFF	maximum positive value
•	
•	
8001	one LSB above mid value
8000	mid value (zero volts)
7FFF	one LSB below mid value
•	
•	
000F	maximum negative value
•	
•	
0000	maximum negative value

CLOSING DATA HEADER:

This is required to end a download sequence and consists of the same format as used in the data header with segment type = 0, 3. See the Data Header Section for more detail.

IEEE FLOATING POINT NUMERICAL CONVERSIONS:

As previously discussed, certain data in the Main Header is to be in standard IEEE Floating Point Format. If your host computer does not have a conversion algorithm, and in particular if you are using BASIC we provide the short BASIC program entitled IE3FP.BAS (included in this Section) which you can incorporate into your control program to provide these conversions as required.

SAMPLE DOWNLOAD DATA PROGRAMS:

There are four (4) sample data download programs included in this section. Examination of these programs will provide a better understanding of the material presented in this Section. In fact you might want to actually enter these programs on your host controller and try downloading one or more of them to your "2020" to gain a better feeling for the remote programming dynamics.

These sample programs are written in BASIC and were developed for use on an IBM PCXT (or compatible) with a CEC (Capital Equipment Corportation, Burlington, Ma.) IEEE-488 interface board model number 01000-00200. This interface board utilizes a TI (Texas Instruments) 9914 bus interface device. You may experience certain bus handshake difficulties with other interface hardware.

RPTTEST0.BAS, RPTTEST1.BAS and RPTEST2.BAS illustrate the use of REPTEAT features using both end-shot and nested loops with loop counters 0 and 1. CONSTANT.BAS shows the use of memory compression when a dc (constant) value is to be loaded into a minimum amount of output memory space. SEGTEST.BAS shows the use of Segmented Output Memory Files. That is, the downloading of multiple (named) files for rapid recall by the subsequent use of "RCL FILENAME."

NOTES:

COMMON FLOATING POINT VALUES (TABLE ET-4)

(Sent left-to-right, one byte per hex pair in string)

SCALING AND OFFSET VALUES

REAL	HEX	REAL	HEX
5.0	40A00000	2.5	40200000
4.9	409CCCCD	2.4	4019999A
4.8	4099999A	2.3	40133333
4.7	40966666	2.2	400CCCCD
4.6	40933333	2.1	40066666
4.5	40900000	2.0	40000000
4.4	408CCCCD	1.9	3FF33333
4.3	4089999A	1.8	3FE66666
4.2	40866666	1.7	3FD9999A
4.1	40833333	1.6	3FCCCCCD
4.0	40800000	1.5	3FC00000
3.9	4079999A	1.4	3FB33333
3.8	40733333	1.3	3FA66666
3.7	406CCCCD	1.2	3F99999A
3.6	40666666	1.1	3F8CCCCD
3.5	40600000	1.0	3F800000
3.4	4059999A	0.9	3F666666
3.3	40533333	0.8	3F4CCCCD
3.2	404CCCCD	0.7	3F333333
3.1	40466666	0.6	3F19999A
3.0	40400000	0.5	3F000000
2.9	4039999A	0.4	3ECCCCCD
2.8	40333333	0.3	3E99999A
2.7	402CCCCD	0.2	3E4CCCCD
2.6	40266666	0.1	3DCCCCCD

CLOCK VALUES

50 ns	3356BF95	1 ms	3A83126F
100 ns	33D6BF95	2 ms	3B03126F
200 ns	3456BF95	5 ms	3BA3D70A
500 ns	350637BD	10 ms	3C23D70A
1 μs	358637BD	20 ms	3CA3D70A
2 μs	360637BD	50 ms	3D4CCCCD
5 μs	36A7C5AC	100 ms	3DCCCCCD
10 μs	3727C5AC	1s	3F800000
100 μs	38D1B717		

FILTER AND NEW VALUES

20 MHz	4B989680	500 kHz	48F42400
10 MHz	4B189680	200 kHz	48435000
5 MHz	4A989680	100 kHz	47C35000
2 MHz	49F42400	50 kHz	47435000
1 MHz	49742400	20 kHz	469C4000

NOTE: These are typical values, but do not list all possible values; other values should be calculated using a suitable IEEE floating point conversion algorithm. Program IE3FP.BAS, included in this Section can be used on IBM PCXT compatible computers.

```
10   CLS
20   'program to send a data set to the 2020
30   '
40   INIT=0 : XMIT=3 : RECV=6 : SEND=9 : SPOLL=12 : PPOLL=15 : ENTER=21
50   D2000%=16 : ADDR%=21 : SYSCONT%=0
60   '
70   DEF SEG = &HC000
80   CALL INIT (ADDR%,SYSCONT%)
90'
100  A$ = SPACE$(255)
110  A$ = "DATA"                                                ASCII 8
120  '
130  CALL SEND (D2000%,A$,STATUS%)                      DECIMAL VALUE =
140  '
150  ' Main header
160  '                                       70   DATA                        III
170  A$ = "MTA UNL LISTEN 16 DATA 56 81 183 23 0 0 0 0 64 0 0 0 0 0 0 0 73
244 36 0 76 62 188 32 0 0 0 0 0 0 0 0"  EOI
180  '
190  CALL XMIT (A$,STATUS%)
200  'GOTO 260                                          EOI
210  ' Data header
220  '
230  A$ = "MTA UNL LISTEN 16 DATA 0 5 0 0 0 5 0 0 0 0"
240  '
250  CALL XMIT (A$,STATUS%)
260  '
270  ' Data header
280  '
290  A$ = "MTA UNL LISTEN 16 DATA 0 1 0 0 0 20 0 0 0 0"
300  '
310  CALL XMIT (A$,STATUS%)
320  '
330  '
340  ' Data
350  '
360  A$ = "MTA UNL LISTEN 16 DATA 0 16 13 135 26 255 40 118 53 238 67 101
80 221 94 85 107 204 121 68 134 187 148 51 161 170 175 34 188 154 202 17
215 137 229 0 242 120 255 240"
370  '
380  CALL XMIT (A$,STATUS%)
390  '
400  ' Data header
410  '
420  A$ = "MTA UNL LISTEN 16 DATA 0 1 0 0 0 20 0 0 0 0"
430  '
440  CALL XMIT (A$,STATUS%)
450  '
460  ' Data
470  '
480  A$ = "MTA UNL LISTEN 16 DATA 128 0 167 136 203 51 231 128 249 173 255
240 249 173 231 128 203 51 167 136 128 0 88 120 52 205 24 128 6 83 0 16 6
83 24 128 52 205 88 120"
```

BILL HERRINGTON 4-7252
GERRY STOFFERS 4-7346, 4-7871

```
490'
500  CALL XMIT (A$,STATUS%)
510  '
520  '
530  ' Data header
540  '
550  A$ = "MTA UNL LISTEN 16 DATA 0 3 0 0 0 20 0 0 0 0"
560'
570  CALL XMIT (A$,STATUS%)
580  '
590  END
```

```
10  CLS
20  'program to send a data set to the 2020
30   '
40  INIT=0 : XMIT=3 : RECV=6 : SEND=9 : SPOLL=12 : PPOLL=15 : ENTER=21
50  D2000%=16 : ADDR%=21 : SYSCONT%=0
60  '
70  DEF SEG = &HC000
80  CALL INIT (ADDR%,SYSCONT%)
90  '
100 A$ = SPACE$(255)
110 A$ = "DATA"
120 '
130 CALL SEND (D2000%,A$,STATUS%)
140 '
150 ' Main header
160 '
170 A$ = "MTA UNL LISTEN 16 DATA 56 81 183 23 0 0 0 0 64 0 0 0 0 0 0 73
244 36 0 76 62 188 32 0 0 0 0 0 0 0 20"
180 '
190 CALL XMIT (A$,STATUS%)
200 '
210 ' Data header
220 '
230 A$ = "MTA UNL LISTEN 16 DATA 0 5 0 1 0 5 0 0 0 0"
240 '
250 CALL XMIT (A$,STATUS%)
260 '
270 ' Data header
280 '
290 A$ = "MTA UNL LISTEN 16 DATA 0 1 0 0 0 20 0 0 0 0"
300 '
310 CALL XMIT (A$,STATUS%)
320 '
330 '
340 ' Data
350 '
360 A$ = "MTA UNL LISTEN 16 DATA 0 16 13 135 26 255 40 118 53 238 67 101 80
221 94 85 107 204 121 68 134 187 148 51 161 170 175 34 1 88 154 202 17 215
137 229 0 242 120 255 240"
370 '
380 CALL XMIT (A$,STATUS%)
390 '
400 ' Data header
410 '
420 A$ = "MTA UNL LISTEN 16 DATA 0 6 0 1 0 0 0 0 0 0"
430 '
440 CALL XMIT (A$,STATUS%)
450 '
460 ' Data header
470 '
480 A$ = "MTA UNL LISTEN 16 DATA 0 1 0 0 0 20 0 0 0 0"
490 '
500 CALL XMIT (A$,STATUS%)
```

```
510  '
520  ' Data
530  '
540  A$ = "MTA UNL LISTEN 16 DATA 128 0 167 136 203 51 231 128 249 173 255
240 249 173 231 128 203 51 167 136 128 0 88 120 52 205 24 128 6 83 0 16 6
83 24 128 52 205 88 120"
550  '
560  CALL XMIT (A$,STATUS%)
570  '
580  '
590  ' Data header
600  '
610  A$ = "MTA UNL LISTEN 16 DATA 0 3 0 0 0 20 0 0 0 0"
620  '
630  CALL XMIT (A$,STATUS%)
640  '
650  END
```

```
10   CLS
20   'program to send a data set to the 2020
30   '
40   INIT=0 : XMIT=3 : RECV=6 : SEND=9 : SPOLL=12 : PPOLL=15 : ENTER=21
50   D2000%=16 : ADDR%=21 : SYSCONT%=0
60   '
70   DEF SEG = &HC000
80   CALL INIT (ADDR%,SYSCONT%)
90   '
100  A$ = SPACE$(255)
110  A$ = "DATA"
120  '
130  CALL SEND (D2000%,A$,STATUS%)
140  '
150  ' Main header
160  '
170  A$ = "MTA UNL LISTEN 16 DATA 56 81 183 23 0 0 0 0 64 0 0 0 0 0 0 73
244 36 0 76 62 188 32 0 0 0 0 0 0 20"
180  '
190  CALL XMIT (A$,STATUS%)
200  '
202  ' Data header
203  '
204  A$ = "MTA UNL LISTEN 16 DATA 0 5 0 0 1 0 0 0 0 0"
205  '
206  CALL XMIT (A$,STATUS%)
207  '
210  ' Data header
220  '
230  A$ = "MTA UNL LISTEN 16 DATA 0 5 0 1 0 5 0 0 0 0"
240  '
250  CALL XMIT (A$,STATUS%)
260  '
270  ' Data header
280  '
290  A$ = "MTA UNL LISTEN 16 DATA 0 1 0 0 0 20 0 0 0 0"
300  '
310  CALL XMIT (A$,STATUS%)
320  '
330  '
340  ' Data
350  '
360  A$ = "MTA UNL LISTEN 16 DATA 0 16 13 135 26 255 40 118 53 238 67 101 80
221 94 85 107 204 121 68 134 187 148 51 161 170 175 34 1 88 154 202 17 215
137 229 0 242 120 255 240"
370  '
380  CALL XMIT (A$,STATUS%)
390  '
400  ' Data header
410  '
420 A$ = "MTA UNL LISTEN 16 DATA 0 6 0 1 0 0 0 0 0 0"
430  '
440  CALL XMIT (A$,STATUS%)
```

```
450   '
460   ' Data header
470   '
480   A$ = "MTA UNL LISTEN 16 DATA 0 1 0 0 0 20 0 0 0 0"
490   '
500   CALL XMIT (A$,STATUS%)
510   '
520   ' Data
530   '
540   A$ = "MTA UNL LISTEN 16 DATA 128 0 167 136 203 51 231 128 249 173 255
240 249 173 231 128 203 51 167 136 128 0 88 120 52 205 24 128 6 83 0 16 6
83 24 128 52 205 88 120"
550   '
560   CALL XMIT (A$,STATUS%)
570   '
580   '
590   ' Data header
600   '
610   A$ = "MTA UNL LISTEN 16 DATA 0 3 0 0 0 20 0 0 0 0"
620   '
630   CALL XMIT (A$,STATUS%)
640   '
650   END
```

```
 10  CLS
 20  'program to send a data set to the 2020
 30  '
 40  INIT=0 : XMIT=3 : RECV=6 : SEND=9 : SPOLL=12 : PPOLL=15 : ENTER=21
 50  D2000%=16 : ADDR%=21 : SYSCONT%=0
 60  '
 70  DEF SEG = &HC000
 80  CALL INIT (ADDR%,SYSCONT%)
 90  '
100  A$ = SPACE$(255)
110  A$ = "DATA"
120  '
130  CALL SEND (D2000%,A$,STATUS%)
140  '
150  ' Main header
160  '
170  A$ = "MTA UNL LISTEN 16 DATA 56 81 183 23 0 0 0 0 64 0 0 0 0 0 0 73
244 36 0 76 62 188 32 0 0 0 0 0 0 20"
180  '
190  CALL XMIT (A$,STATUS%)
200  '
210  ' Data header
220  '
230  A$ = "MTA UNL LISTEN 16 DATA 0 1 0 0 0 20 0 0 0 0"
240  '
250  CALL XMIT (A$,STATUS%)
260  '
270  '
280  ' Data
290  '
300  A$ = "MTA UNL LISTEN 16 DATA 0 16 13 135 26 255 40 118 53 238 67 101 80
221 94 85 107 204 121 68 134 187 148 51 161 170 175 34 188 154 202 17 215
137 229 0 242 120 255 240"
310  '
320  CALL XMIT (A$,STATUS%)
330  '
340  ' Data header
350  '
360  A$ = "MTA UNL LISTEN 16 DATA 0 1 0 0 0 20 0 0 0 0"
370  '
380  CALL XMIT (A$,STATUS%)
390  '
400  ' Data
410  '
420  A$ = "MTA UNL LISTEN 16 DATA 128 0 167 136 203 51 231 128 249 173 255
240 249 173 231 128 203 51 167 136 128 0 88 120 52 205 24 128 6 83 0 16 6
83 24 128 52 205 88 120"
430  '
440  CALL XMIT (A$,STATUS%)
450  '
460  '
470  ' Data header
480  '
```

```
490  A$ = "MTA UNL LISTEN 16 DATA 0 2 0 0 0 40 200 0 0 0"
500  '
510  CALL XMIT (A$,STATUS%)
520  '
530  '
540  ' Data header
550  '
560  A$ = "MTA UNL LISTEN 16 DATA 0 3 0 0 0 20 0 0 0 0"
570  '
580  CALL XMIT (A$,STATUS%)
590  '
600  END
```

9-20

```
10   KEY OFF
20   CLS
30   'program to send a data set to the 2020
40   '
50   INIT=0 : XMIT=3 : RECV=6 : SEND=9 : SPOLL=12 : PPOLL=15 : ENTER=21
60   D2000%=16 : ADDR%=21 : SYSCONT%=0
70   '
80   DEF SEG = &HC000
90   CALL INIT (ADDR%,SYSCONT%)
100  '
110  A$= "ECHO = 1":PRINT A$:CALL SEND (D2000%,A$,STATUS%)
111  A$= "FASTIO = 1":PRINT A$:CALL SEND (D2000%,A$,STATUS%)
115  A$= "RUN":PRINT A$:CALL SEND (D2000%,A$,STATUS%)
120  A$ = SPACE$(255)
130  'A$ = "DATA":GOSUB 220
140  A$ = "DATA TEST1":GOSUB 220
150  A$ = "DATA TEST2":GOSUB 520
160  A$ = "DATA TEST3":GOSUB 820
170  A$ = "DATA TEST4":GOSUB 220
180  A$ = "DATA TEST5":GOSUB 220
190  A$ = "DATA TEST6":GOSUB 220
200  A$ = "DATA TEST7":GOSUB 220
201  A$ = "DATA TEST8":GOSUB 220
202  A$ = "DATA TEST9":GOSUB 520
203  A$ = "DATA TEST10":GOSUB 820
204  A$ = "DATA TEST11":GOSUB 820
205  A$ = "DATA TEST12":GOSUB 820
206  A$ = "DATA TEST13":GOSUB 820
207  A$ = "DATA TEST14":GOSUB 820
208  A$ = "DATA TEST15":GOSUB 820
209  A$ = "DATA TEST16":GOSUB 820
210  PRINT "ALL DONE":RUN"CMD2020
220  PRINT A$
230  CALL SEND (D2000%,A$,STATUS%)
240  '
250  ' Main header
260  '
270  A$ = "MTA UNL LISTEN 16 DATA 56 81 183 23 0 0 0 64 0 0 0 0 0 0 0 73
244 36 0 76 62 188 32 0 0 0 0 0 0 0 20"
280  '
290  CALL XMIT (A$,STATUS%)
300  '
310  ' Data header
320  '
330  A$ = "MTA UNL LISTEN 16 DATA 0 1 0 0 0 20 0 0 0 0"
340  '
350  CALL XMIT (A$,STATUS%)
360  '
370  '
380  ' Data
390  '
```

```
400   A$ = "MTA UNL LISTEN 16 DATA 128 0 167 136 203 51 231 128 249 173 255
240 24 9 173 231 128 203 51 167 136 128 0 88 120 52 205 24 128 6 83 0 16 6
83 24 128 52 205 88 120"
410   '
420   CALL XMIT (A$,STATUS%)
430   '
440   '
450   ' Data header
460   '
470   A$ = "MTA UNL LISTEN 16 DATA 0 3 0 0 0 20 0 0 0 0"
480   '
490   CALL XMIT (A$,STATUS%)
500   '
510   RETURN
520   '
530   ' Main header
540   '
550   PRINT A$
560   CALL SEND (D2000%,A$,STATUS%)
570   A$ = "MTA UNL LISTEN 16 DATA 56 81 183 23 0 0 0 0 64 0 0 0 0 0 0 73
244 36 0 76 62 188 32 0 0 0 0 0 0 20"
580   '
590   CALL XMIT (A$,STATUS%)
600   '
610   ' Data header
620   '
630   A$ = "MTA UNL LISTEN 16 DATA 0 1 0 0 0 20 0 0 0 0"
640   '
650   CALL XMIT (A$,STATUS%)
660   '
670   '
680   ' Data
690   '
700   A$ = "MTA UNL LISTEN 16 DATA 128 0 153 150 179 44 204 195 230 89 255 240
230 89 204 195 179 44 153 150 128 0 102 105 76 211 51 60 25 166 0 16 25 166
51 60 7 6 211 102 105"
710   '
720   CALL XMIT (A$,STATUS%)
730   '
740   '
750   ' Data header
760   '
770   A$ = "MTA UNL LISTEN 16 DATA 0 3 0 0 0 20 0 0 0 0"
780   '
790   CALL XMIT (A$,STATUS%)
800   '
810   RETURN
820   '
830   ' Main header
840   '
850   PRINT A$
860   CALL SEND (D2000%,A%,STATUS%)
870   A$ = "MTA UNL LISTEN 16 DATA 56 81 183 23 0 0 0 0 64 0 0 0 0 0 0 73
244 36 0 76 62 188 32 0 0 0 0 0 0 20"
880   '
```

```
890  CALL XMIT (A$,STATUS%)
900  '
910  ' Data header
920  '
930  A$ = "MTA UNL LISTEN 16 DATA 0 1 0 0 0 20 0 0 0 0"
940  '
950  CALL XMIT (A$,STATUS%)
960  '
970  '
980  ' Data
990  '
1000 A$ = "MTA UNL LISTEN 16 DATA 255 240 255 240 255 240 255 240 255 240 255
24 0 255 240 255 240 255 240 255 240 0 16 0 16 0 16 0 16 0 16 0 16 0 16 0 16
0 16 0 16"
1010 '
1020 CALL XMIT (A$,STATUS%)
1030 '
1040 '
1050 ' Data header
1060 '
1070 A$ = "MTA UNL LISTEN 16 DATA 0 3 0 0 0 20 0 0 0 0"
1080 '
1090 CALL XMIT (A$,STATUS%)
1100 '
1110 RETURN
1120 END
```

```
10   'IE3FP.TST
20   '
30   ' TO TEST IEEE FLOATING POINT CONVERSION ROUTINE
40   '
50   'D. ESTRICH @ DATA PRECISION 6-10-86
60   '
70   INPUT "ENTER THE NUMBER ".FP#
80   GOSUB 240
90   GOSUB 150
100  PRINT ""
110  PRINT ""
120  GOTO 70
130  END
140  '
150  A=B1%:B=B2%:C=B3%:D=B4%
160  IF A=0 AND B=0 AND C=0 AND D=0 THEN FP=0:GOTO 210
170  S=(A AND 128)/128
180  E=(A AND 127)*2+(B AND 128)/128-127
190  M#=(((B AND 127)+128)*2^16+C*2^8+D)/2^23
200  FP#=(-1)^S*2^E*M#
210  PRINT "THE NUMBER IS  ";FP#
220  RETURN
230  '*****conversion routine*********************************************
240  SIGNFP%=SGN(FP#)
250  IF SIGNFP%=-1 THEN FP#=FP#*(-1) ELSE SIGNFP%=0
260  IF FP#=0 THEN B1%=0 AND B2%=0 AND B3%=0 AND B4%=0:HEAD$="0 0 0 0 ":RETURN
270  EXPON#=LOG(FP#) *1.442695
280  IEXPON%=INT(EXPON#)
290  MANT#=FP#*(2^(23-IEXPON%))-2^23
300  IF MANT#>8388607! THEN IEXPON%=IEXPON%+1:GOTO 290
310  B=INT(MANT#/65536!)
320  C1#=MANT#-B*65536!
330  C=INT(C1#/256)
340  D=INT(C1#-C*256)
350  B4%=D
360  B3%=C
370  IEXPON%=IEXPON%+127
380  B2%=(IEXPON% AND 1)*128+B
390  IF SIGNFP%=-1 THEN SIGNFP%=1
400  B1%=(IEXPON% AND 254)/2+SIGNFP%*128
410  HEAD$=STR$(B1%)+" "+STR$(B2%) +" "+STR$(B3%) +" "+STR$(B4%) +" "
420  PRINT " BYTES ARE   ":HEAD$
430  RETURN
```

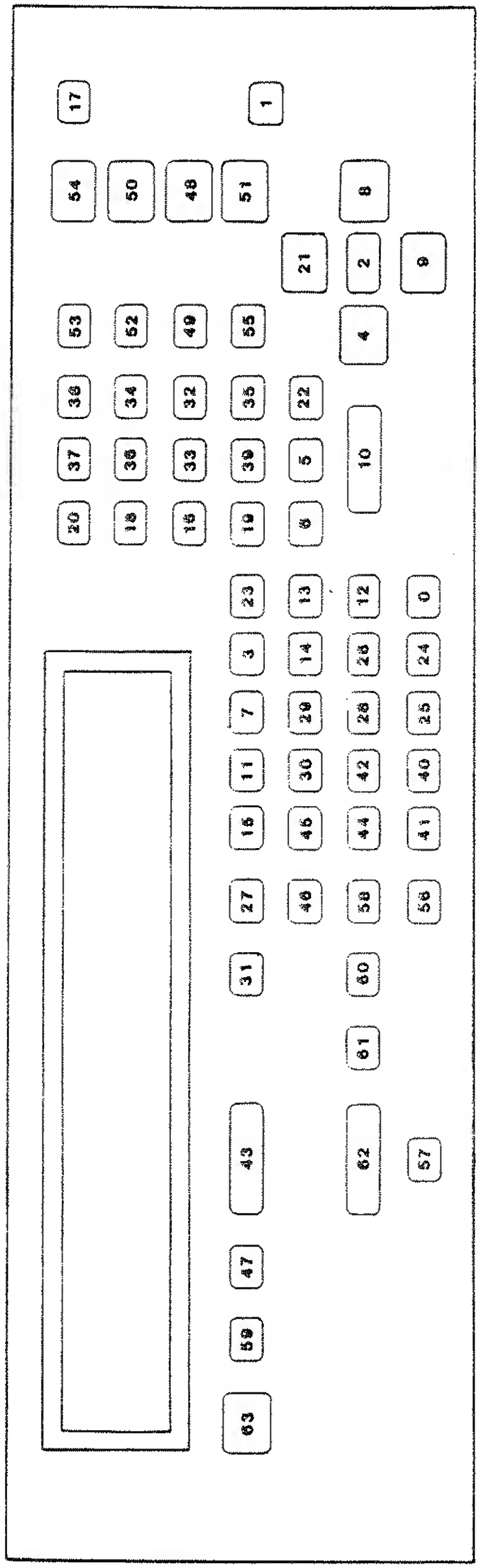


FIGURE FF-1

Model 2000:
The model "2000" is intended for ATE (Automatic Test Equipment) applications where operator interface with the front panel is not required. Therefore the model "2000" can be considered to be equivalent to a model "2020" wherein the front panel, keyboard and display are removed and replaced with a simplified front as shown in figure FF - 1. Additionally the model "2000" comes with GPIB (IEEE-488) as a standard feature. RS232 can also be supplied on the "2000" as an option.

Since the model "2000" essentially emulates a REMOTE mode only version of the "2020", the Remote Programming and Control Section (section E) of the manual should guide the user in the utilization and operation of the "2000". However, the other manual sections that relate to key board and display features are good background material for the operation of the ATE version (mdl 2000). This is especially true when one chooses to emulate key strokes to the non-existent key board by means of the key codes, as well as gaining a solid understanding of the Standard Function, POLY mode, and OP Code features that are detailed in their respective sections.

One point worth noting here is that in the OP 6000 mode which is used to download captured data from the DATA PRECISION WAVEFORM ANALYZER (Model 6000), the 2020 acts as a system controller for the Model 6000. When the model 2020 is put into a REMOTE mode it expects to operate with another controller, as does the model 2000 at all times; the prevents either the 2000 or a REMOTE MODE 2020 from communicating with a Model 6000 WAVEFORM ANALYZER for the purpose of down-loading captured data files.

Figure FF-1 shows the front panel of a model 2000. The FUNCTION OUT AND TRIGGER IN connectors have the same purpose as in the case of the model 2020. The Status Indicators serve the following purpose:

POWER
Primary Power is applied to the system.

FAIL
A Fatal Error has occurred. The controller should poll at this time to determine the nature of the error.

ACTIVE
An output waveform is in process and currently exists at the Function Out.

RUN
The RUN/STOP state is currently equal to RUN.

ERROR
A communications error has occurred. At this time the controller should poll to determine the nature of this error.

REMOTE
The system has been addressed by the controller and is on line.

TALK
The system is in the TALK mode.

LISTEN
The system is in the LISTEN Mode.

SRQ
A Service Request is pending from the 2000.

NOTE: WHEN RS232 IS INSTALLED AND SELECTED AS THE COMMAND (CMD) DEVICE THE GPIB STATUS INDICATORS; REMOTE, LISTEN, TALK, AND SRQ ARE NOT ACTIVE.

MODEL 2000 NOTES:

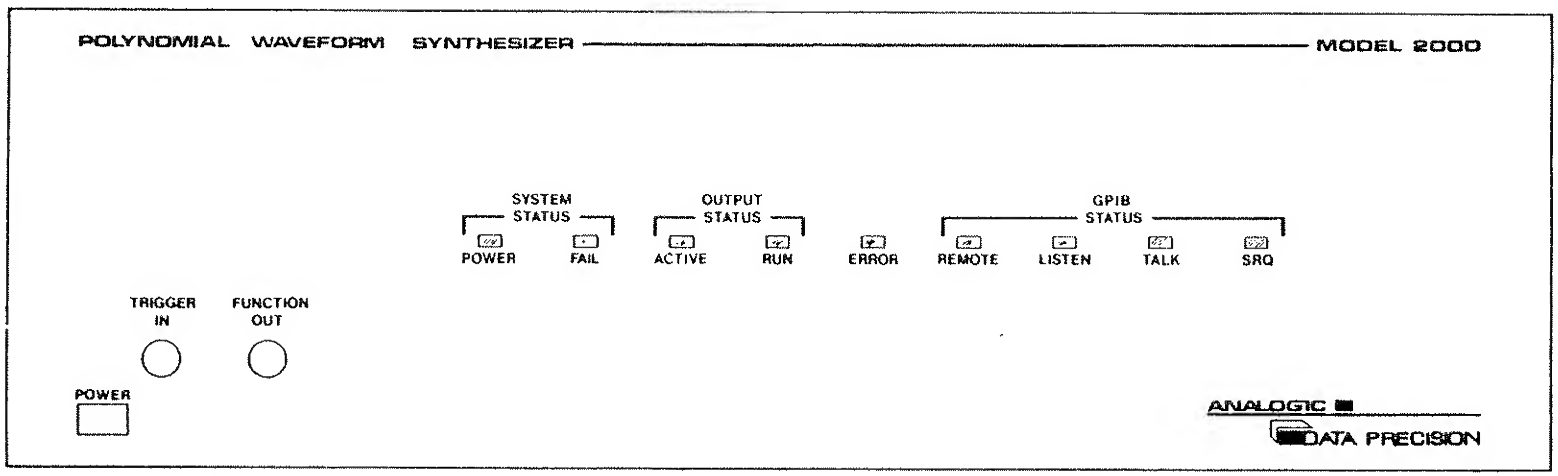

POLYNOMIAL WAVEFORM SYNTHESIZER
MODEL 2000
SYSTEM STATUS
POWER
FAIL
OUTPUT STATUS
ACTIVE
RUN
ERROR
GPIB STATUS
REMOTE
LISTEN
TALK
SRQ
TRIGGER IN
FUNCTION OUT
POWER
ANALOGIC
DATA PRECISION

FIGURE FF-1

2020/2000 SPECIFICATIONS

Number of Outputs
1 analog
1 16-bit digital*

Non-Volatile Equation Memory
Up to 78K characters
(30K standard)

Memory Size (output data memory)
Up to 512K data points
64K standard 25 MHz model
128K standard 100 MHz model

Max. Data Clock Period
25 ns/10 ns (optional)

Min. Data Clock Period
687.173s

Clock Rate Control
Each 0.05% (approx. 5 trillion steps)

Clock Stability
100 ppm

External Clock Control
dc to 100 MHz

Resolution (number of bits) for Full Scale Output
12 bits analog
16 bits digital

Analog Output Impedance
Active: 50Ω
Inactive: >10 MΩ

Max. Analog Output (into 50Ω)
10 Vp-p (±5V)

Max. Analog Output (open circuit)
20 Vp-p (±10V)

Data Point Rise or Fall Time (full scale)
≤10 ns

Data Point Settling Time
<60 ns to 1%

Slew Rate
>800 V/μs into 50Ω
>1600 V/μs into 1 MΩ

Overshoot (full scale step transition)
None

Analog Output Bandwidth
>35 MHz

Amplitude Flatness
±0.1 dB dc to 500 kHz;
±1.5 dB @ 25 MHz;
−3 dB @ 35 MHz

Residual Noise Including Clock Feed-Through (referenced to full scale output)
−72 dB

Glitch Energy
Peak voltage: <1% of p-p signal amplitude
Duration: <10 ns half power input

Absolute Accuracy
±1% of reading, ±10 mV (when terminated by 50Ω)

**Optional on 100 MHz version*

Relative Accuracy (includes linearity)
±0.025% of full scale

Sine Wave Purity (harmonic distortion)
1 kHz: ≤0.1%; 25 kHz; ≤0.15%; 2 MHz; ≤0.5%

DC Drift
≤ +0.5% of full scale over full temp. range

Noise Generator Output
White Gaussian, from 0.02 Hz to selected bandwidth and can be either separate or summed with the signal

Noise Bandwidth
Selectable 2 kHz, 20 kHz, 200 kHz, 2 MHz

Memory Management
Virtual memory is achieved via dynamic looping and constant compression

Programmable (independent) DC Offset
±5V in 1.25 mV steps

Programmable DC Offset Accuracy
±2%

Trigger and Gating Modes
10

Trigger Jitter (uncertainty)
≤10 ns

External Clock Jitter
≤ ±500 ps

Internal Lumped Constant Filters
10 (internal) user selectable in a 1,2,5 sequence from 20 kHz to 20 MHz plus no filter

External Data Ports
RS232, IEEE-488**

Download/Upload Data Transfer Rate Via the GPIB-488 Bus
>300K bytes/s (optional)
>2K bytes/s (standard)

Minimum Waveform Length***
16 points 100 MHz model
8 points 25 MHz model

Horizontal Resolution
1 data point

Attenuation Control
Amplitude setting can be made from ±3.5 mV to ±5V in 0.01% increments with 12-bit resolution preserved

Operating Temperature
0°C to 40°C

Power Consumption
75 watts

Dimensions
Height: 5.5" (13.97 cm)
Width: 16.5" (41.91 cm)
Depth: 17" (43.18 cm)

Weight
25 lbs. (11.3 kg)

***Data ports are optional except IEEE-488 is standard on Model 2000*
****Sync output disabled when waveform length is less than 32 points (100 MHz model), 16 points (25 MHz model).*

NOTES:

UX: NEWNAME = ABC